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Katayama

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(54) **COOLING SYSTEM FOR OUTBOARD MOTOR**

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(30) **Foreign Application Priority Data**

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(52) **U.S. Cl.** **123/41.29**; 440/88
(58) **Field of Search** 123/41.29, 41.31, 123/41.33, 540, 456; 440/88

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,438,962 A	8/1995	Iwata et al.
5,823,835 A	10/1998	Takahashi et al.
5,921,829 A	7/1999	Iwata
5,975,032 A	11/1999	Iwata
5,980,340 A	11/1999	Okamoto
5,984,743 A *	11/1999	Wada et al. 440/88
6,184,599 B1	2/2001	Okabe et al.

FOREIGN PATENT DOCUMENTS

JP	6-42345	2/1994
JP	11-324696	11/1999

* cited by examiner

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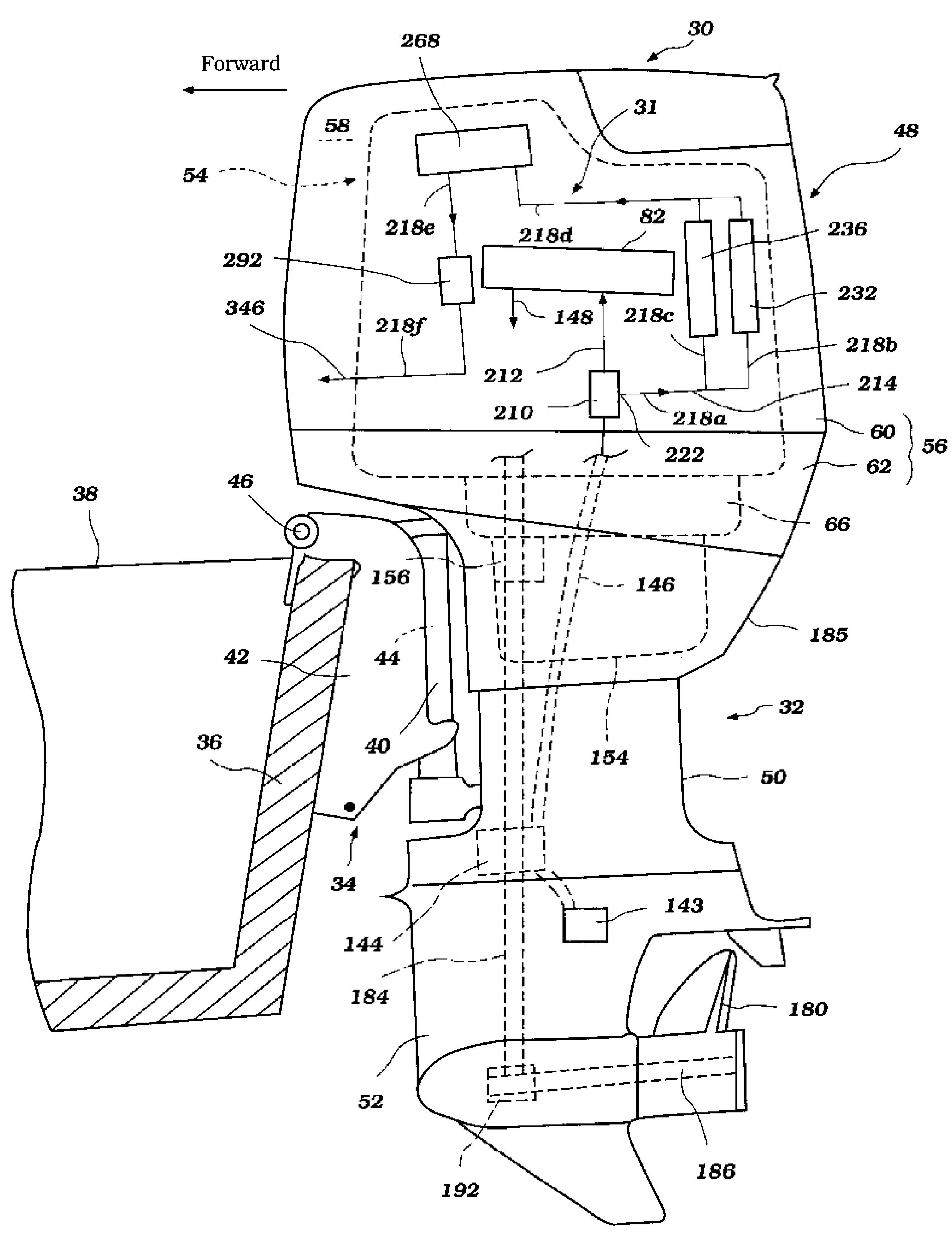
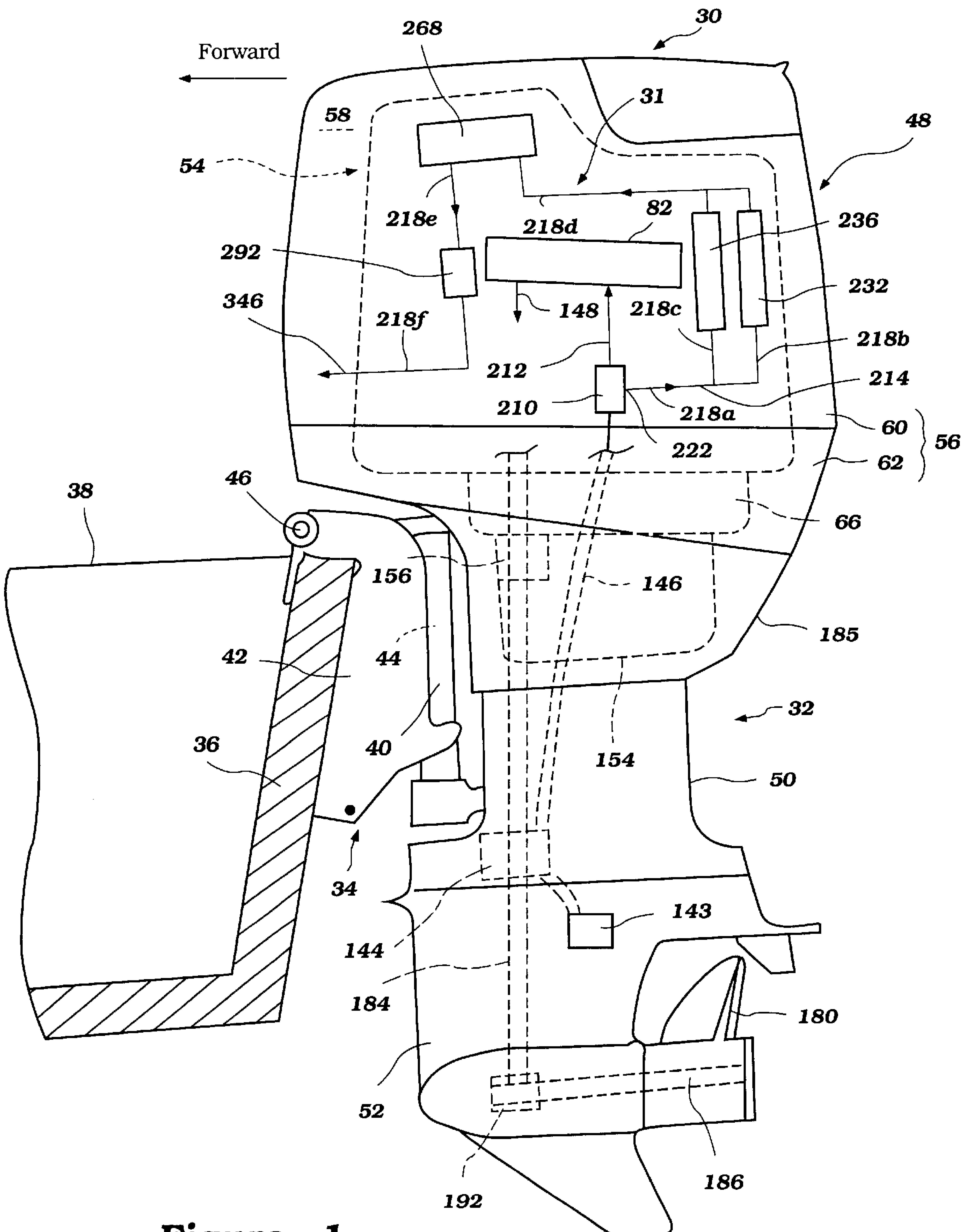
(57) **ABSTRACT**

An engine for an outboard motor includes engine components disposed around the engine body. A cooling system includes a first water passage cooling the engine body and a second water passage branching off from the first water passage upstream the engine body and extending through the engine components. One engine component is generally positioned above the engine body. Two engine components are positioned on different sides of the engine body. The first and second water passages have separate discharge ports. The engine components are made of a metal material. The second water passage is defined by tubular members made of a corrosion-resistant material and the respective tubular members are embedded in the respective bodies of the engine components.

33 Claims, 10 Drawing Sheets

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268
30
58
31
48
54
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218d
82
236
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232
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218f
148
218c
218b
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210
218a
60
56
222
62
38
46
66
156
146
185
42
44
32
36
40
154
50
34
143
144
184
180
52
186
192

Figure 1

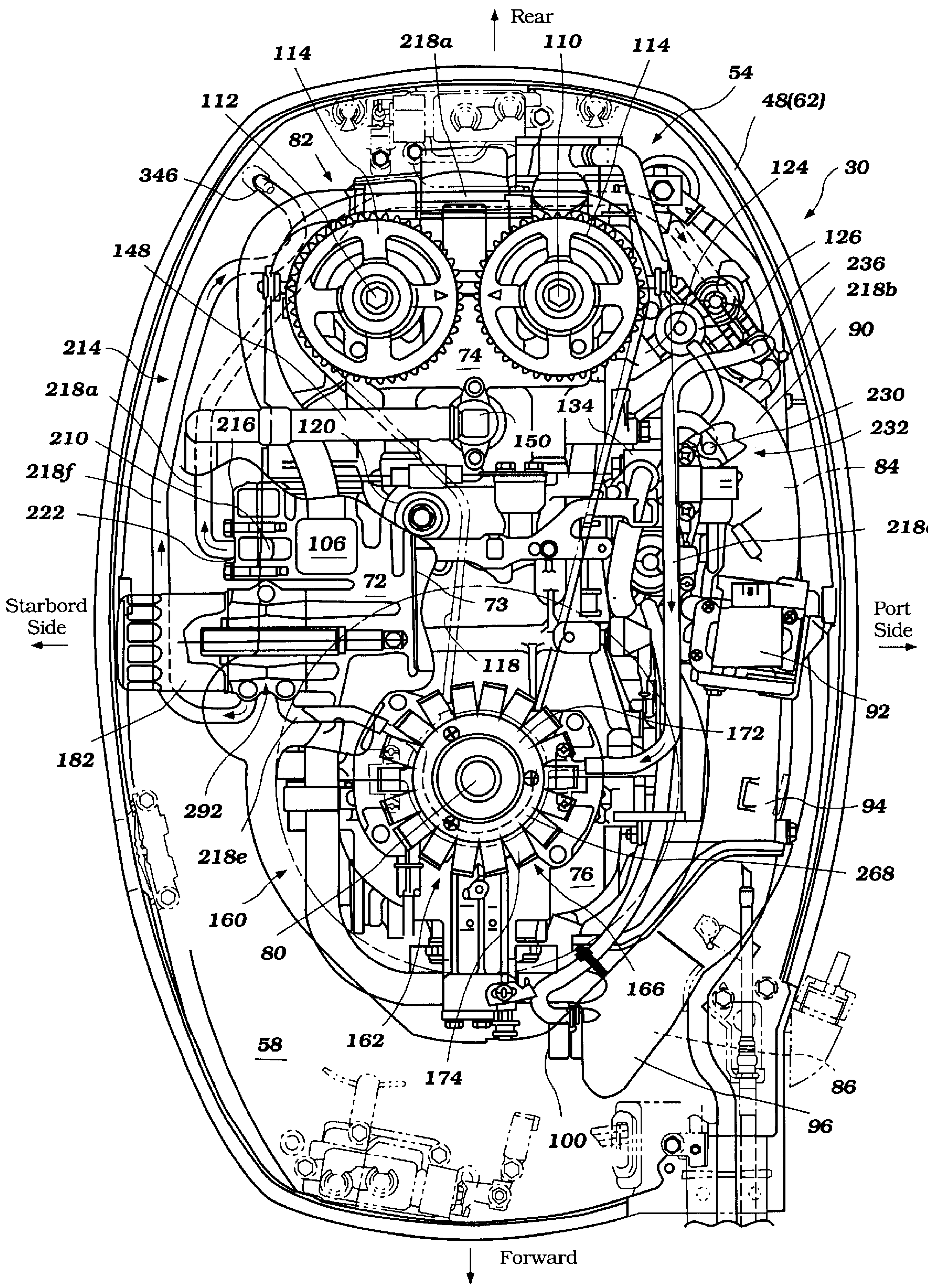
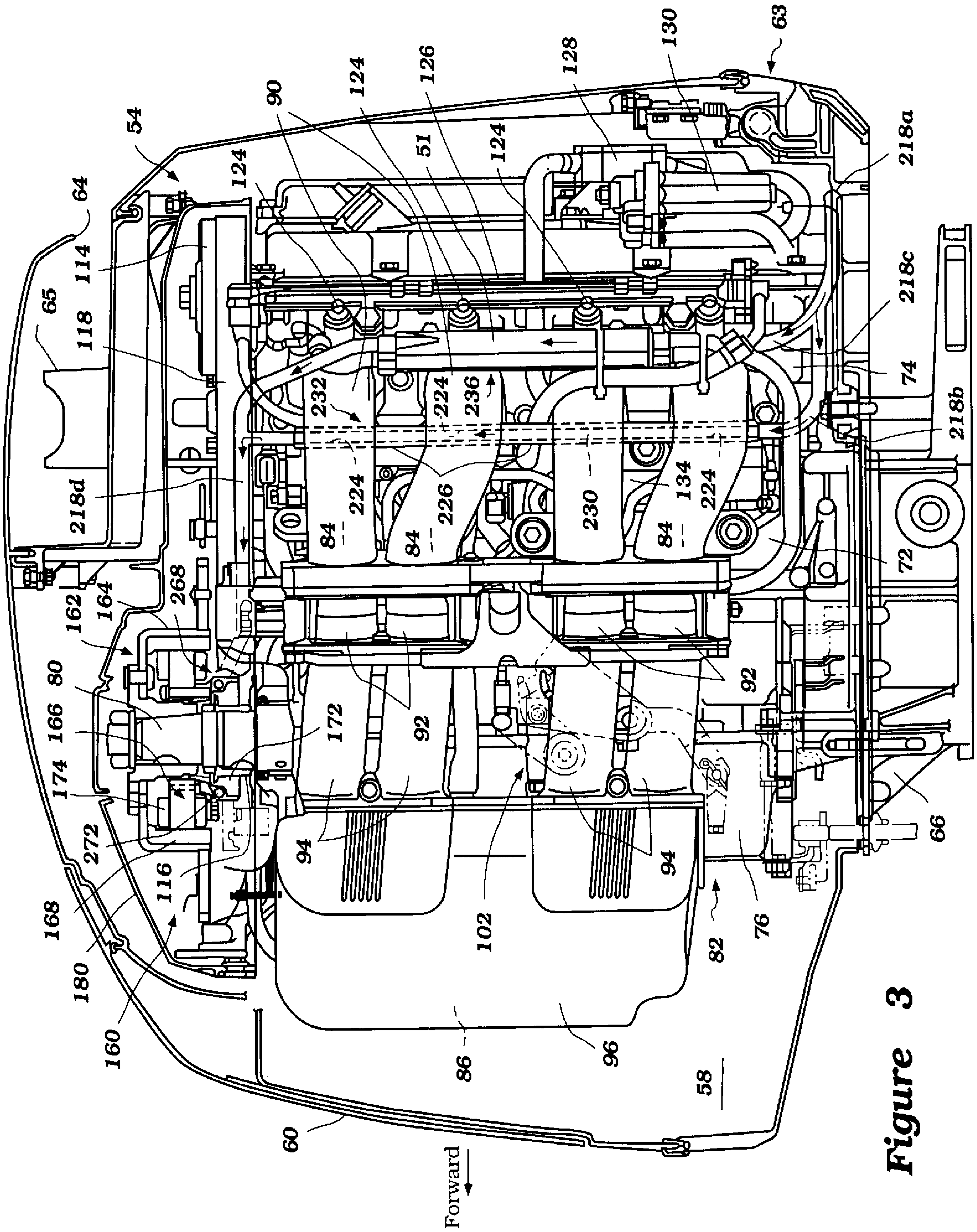

Rear
218a
110
114
114
54
48(62)
112
82
124
30
346
126
236
148
218b
90
214
74
218a
230
134
216
120
232
210
150
84
218f
222
218d
106
72
73
Starbord Side
Port Side
118
92
172
182
94
292
218e
76
268
160
80
166
58
162
174
86
96
100
Forward

Figure 2


54
64
65
114
118
124
90
51
124
126
128
130
63
218a
218c
74
218b
72
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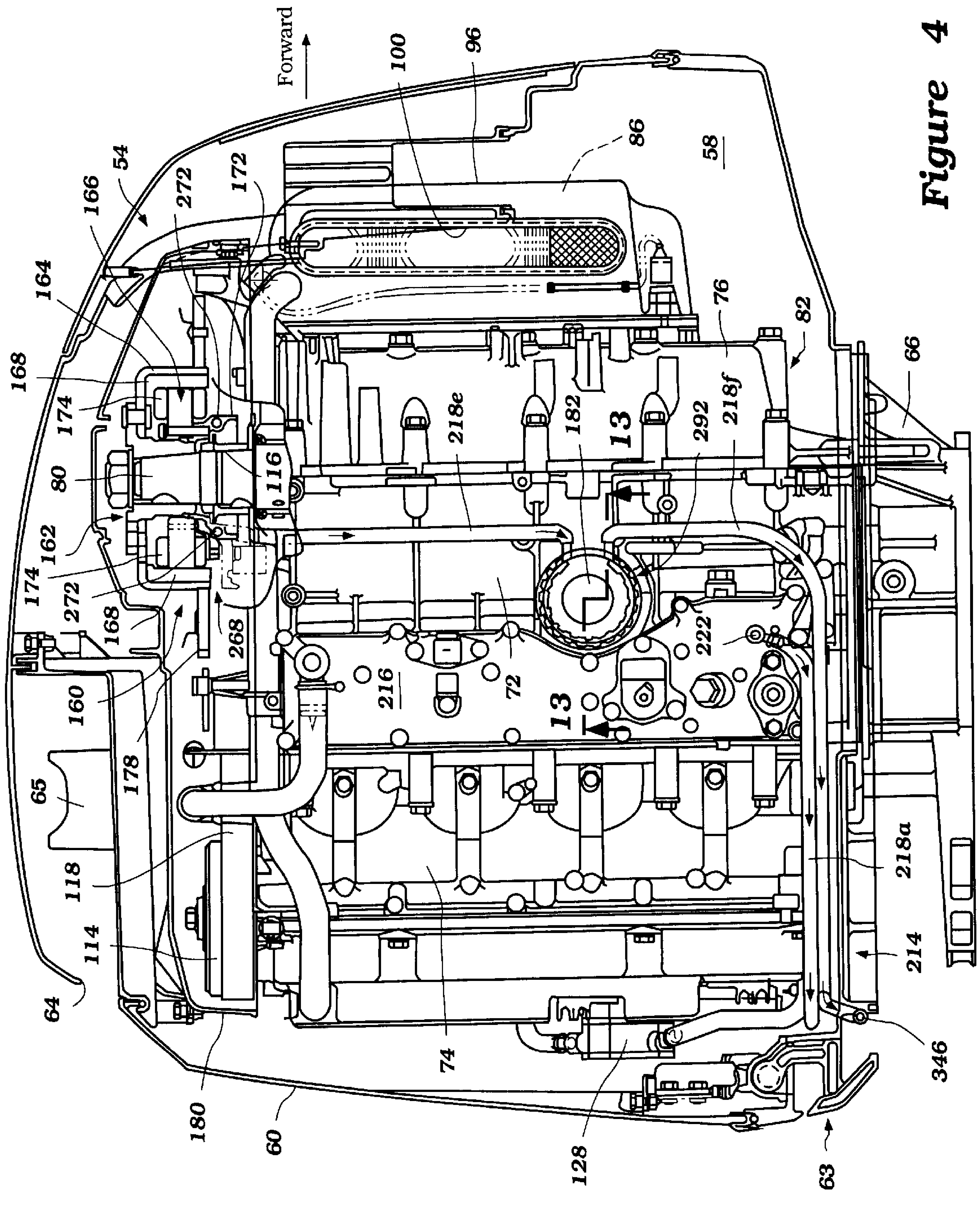
218d
232
224
236
226
230
134
84
92
94
96
86
102
82
76
58
60
162
164
268
80
166
172
174
272
116
168
180
160
Forward

Figure 3


Forward
100
96
86
58
54
166
272
172
164
168
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80
116
218e
182
13
292
218f
76
82
66
162
174
272
168
268
222
216
72
13
160
178
65
118
114
74
218a
214
346
64
180
60
128
63

Figure 4

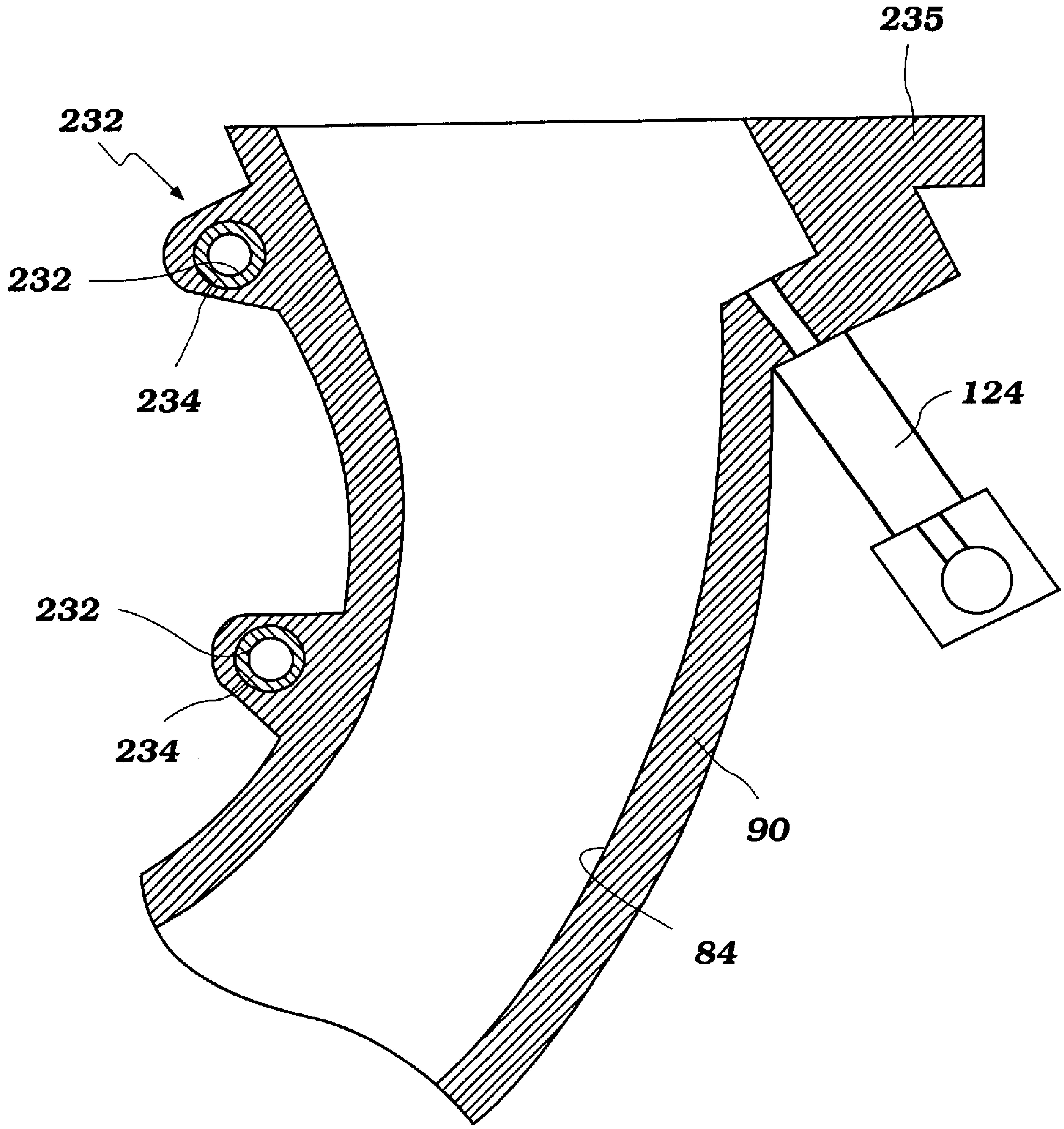
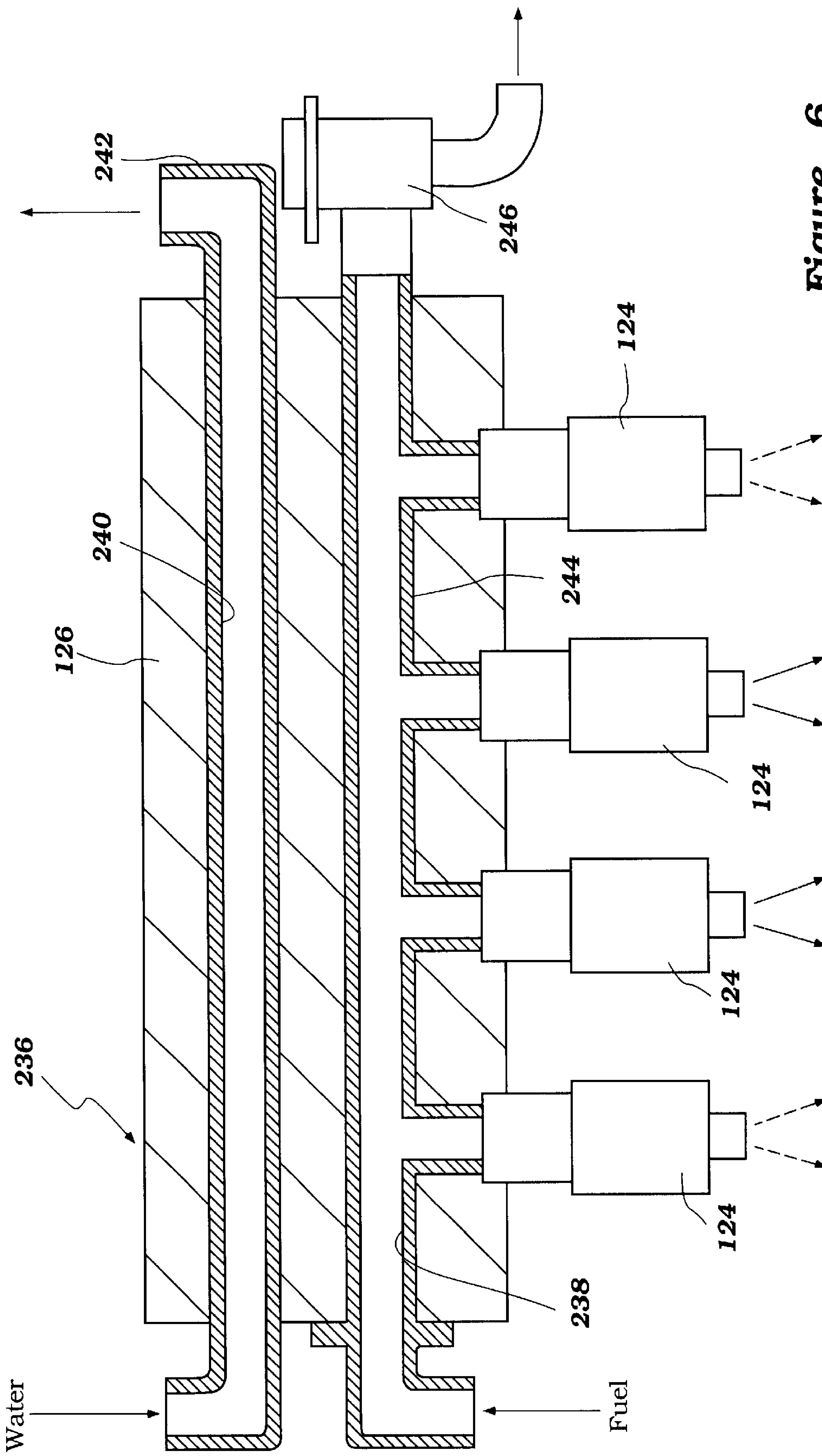


Figure 5



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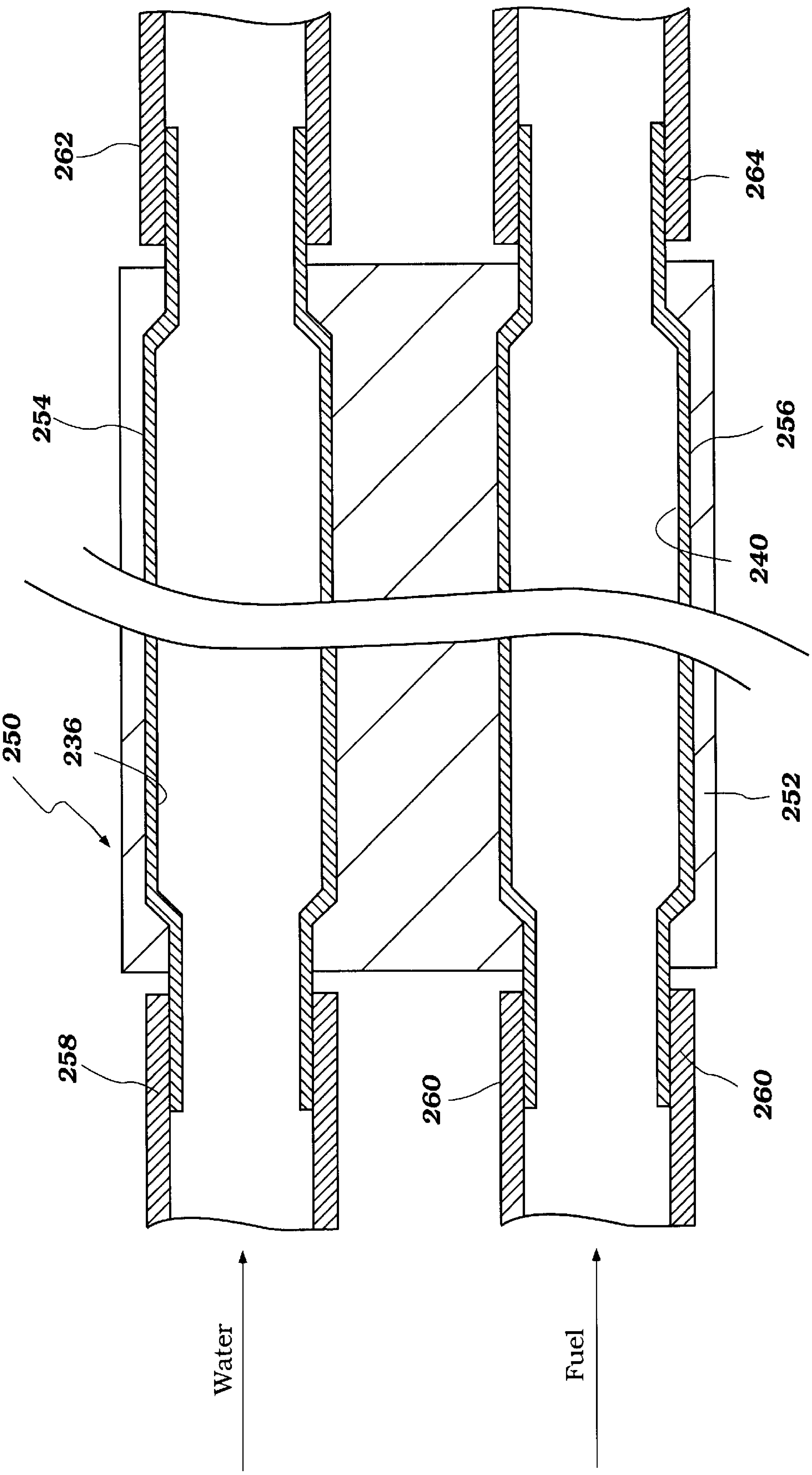

Figure 7

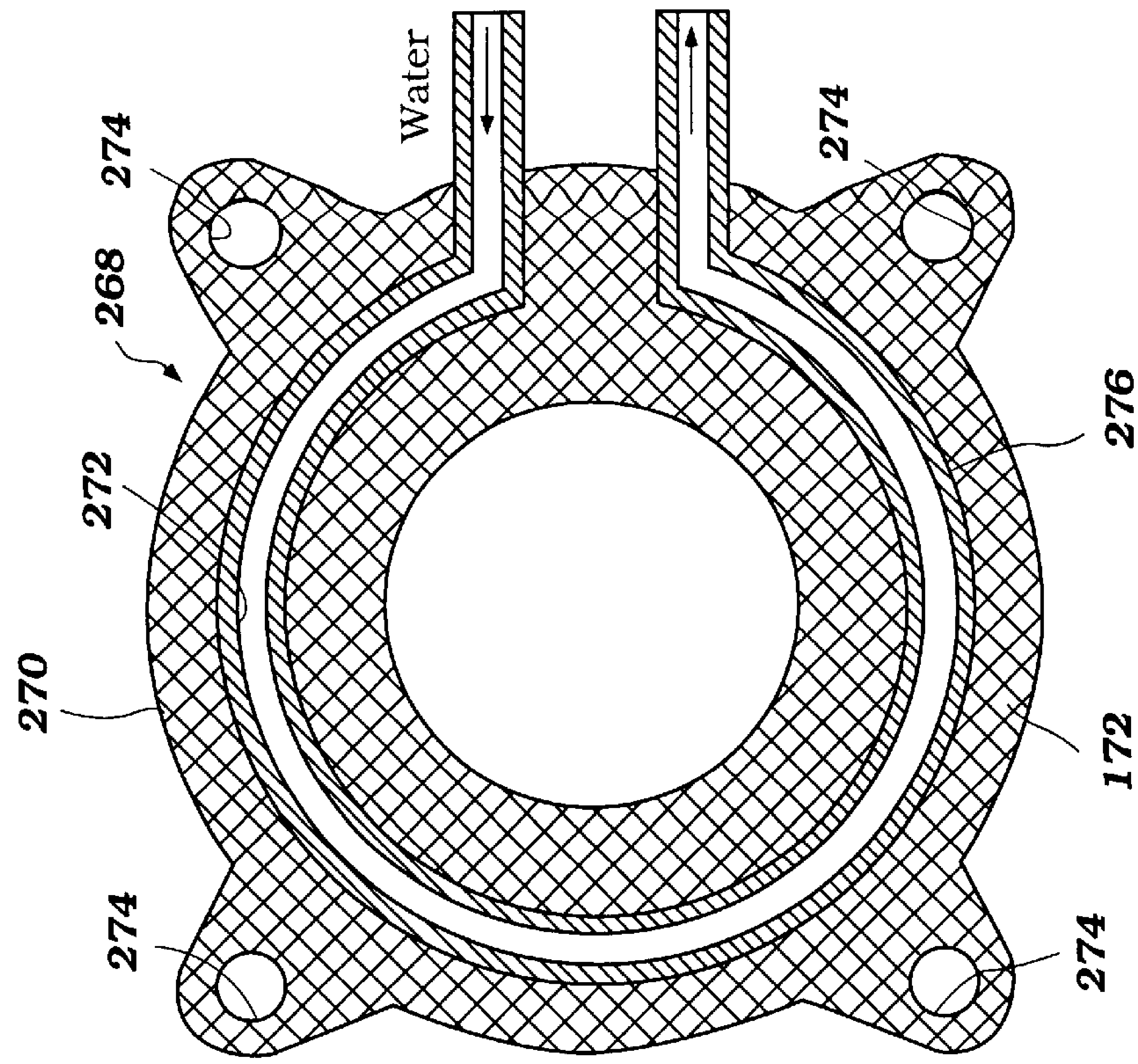

Figure 10

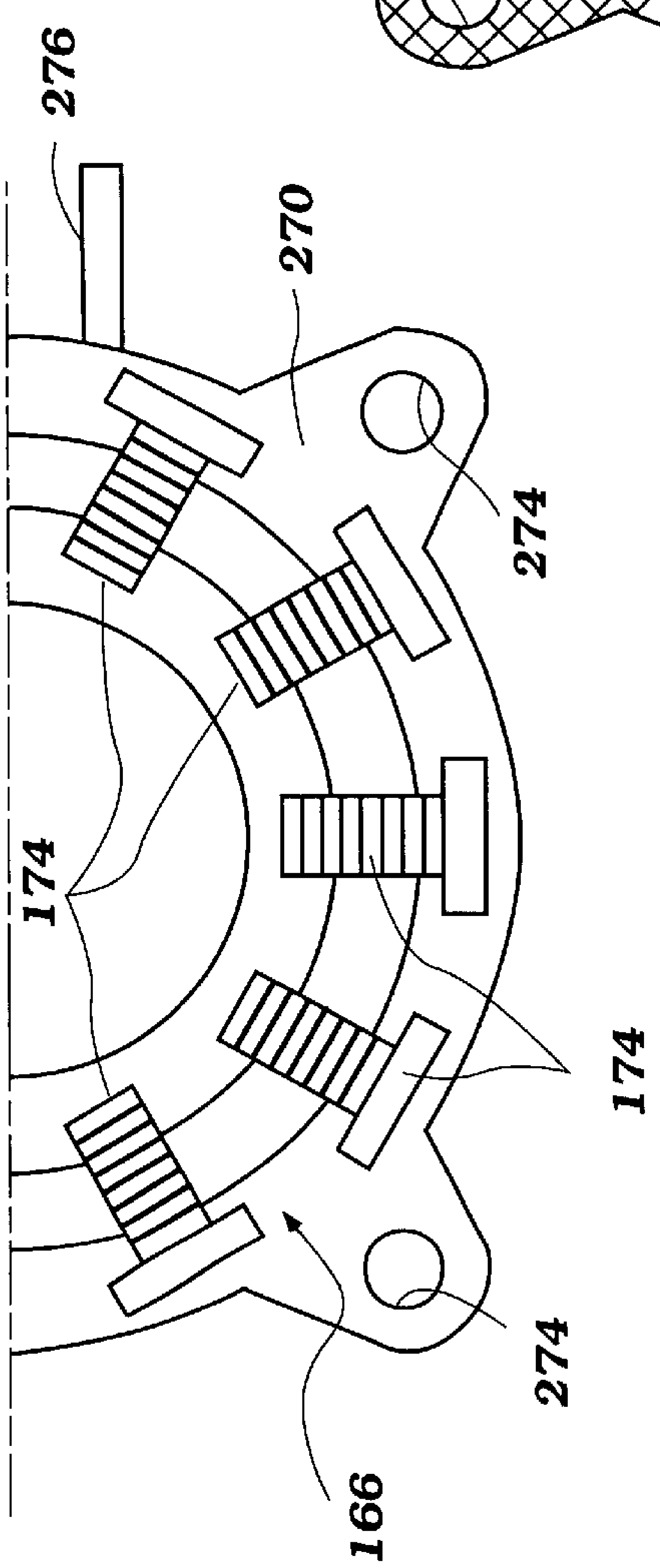

Figure 8

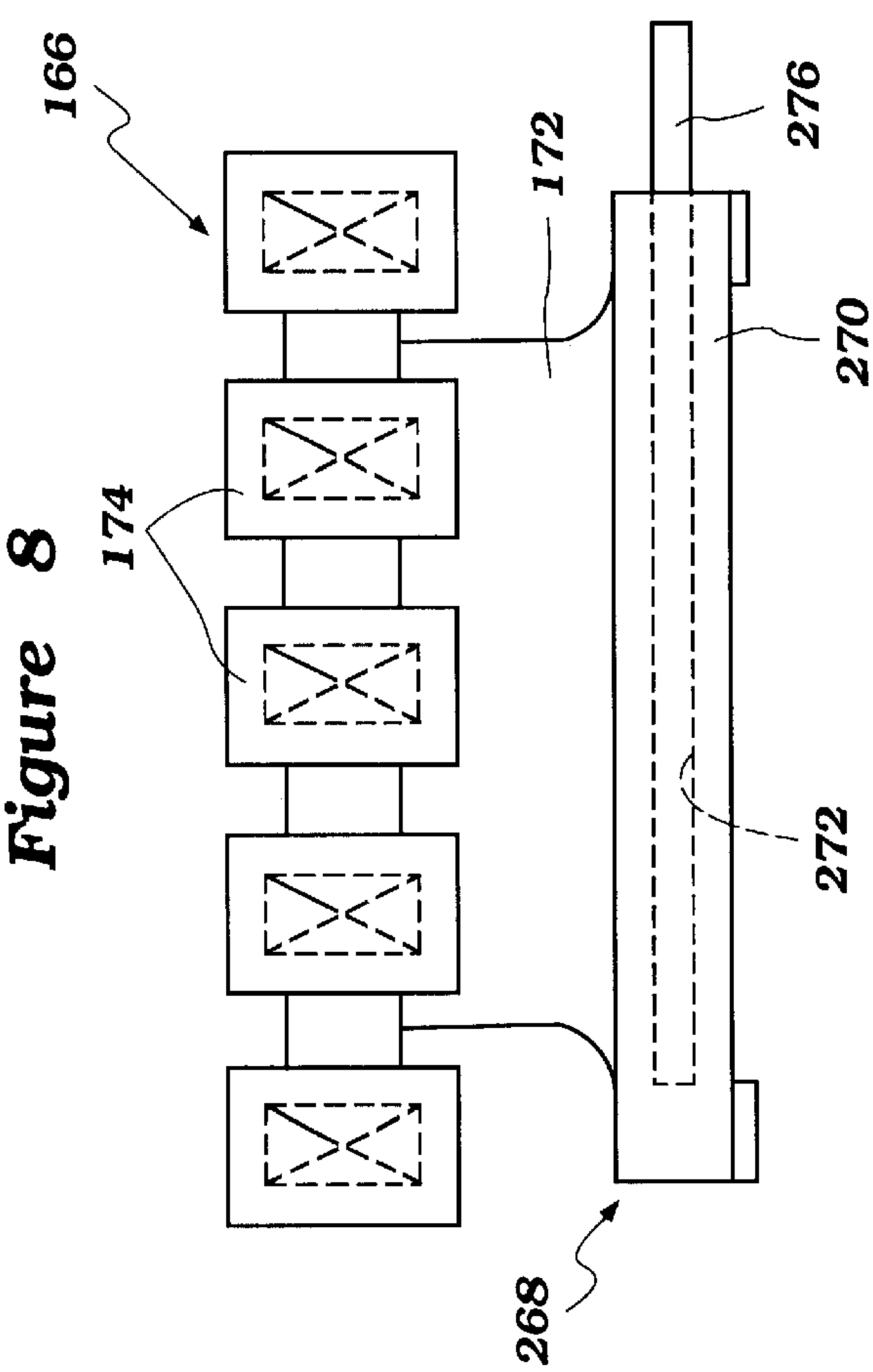

Figure 9

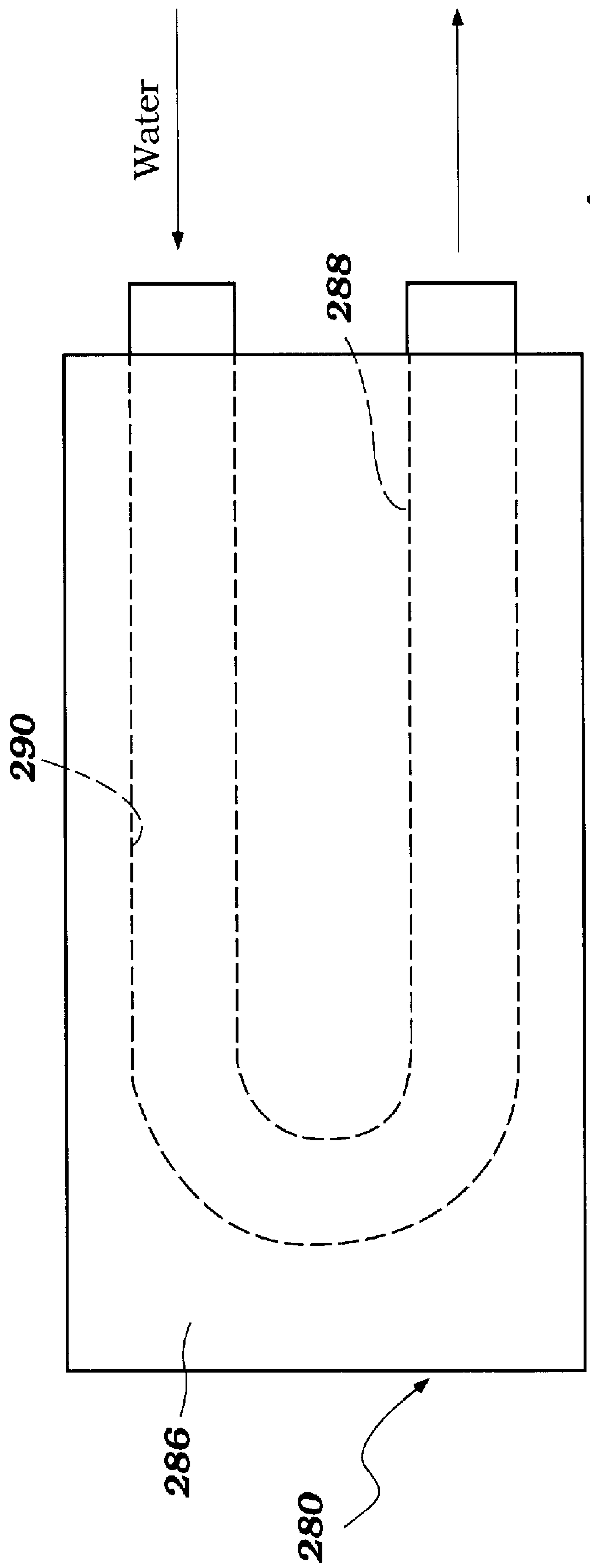

Figure 11

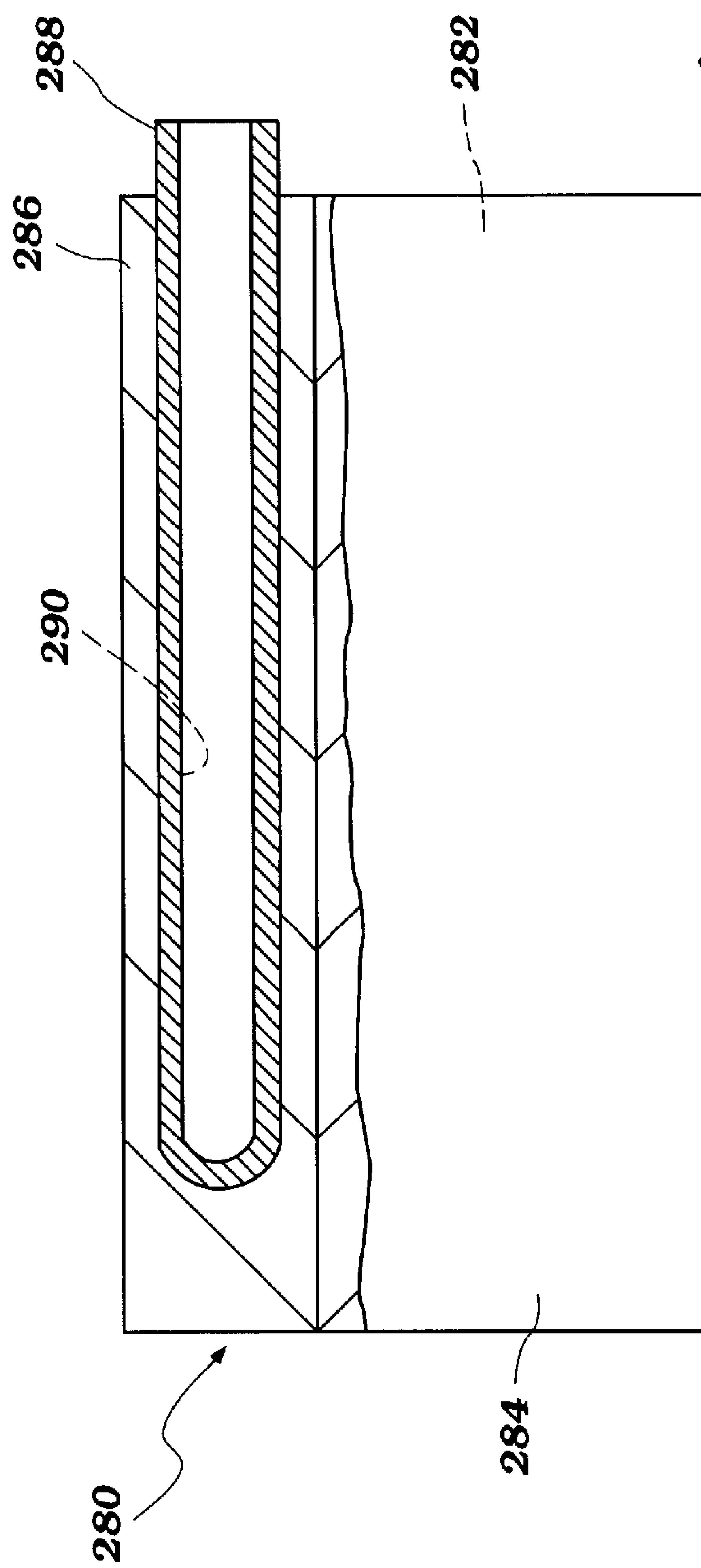

Figure 12

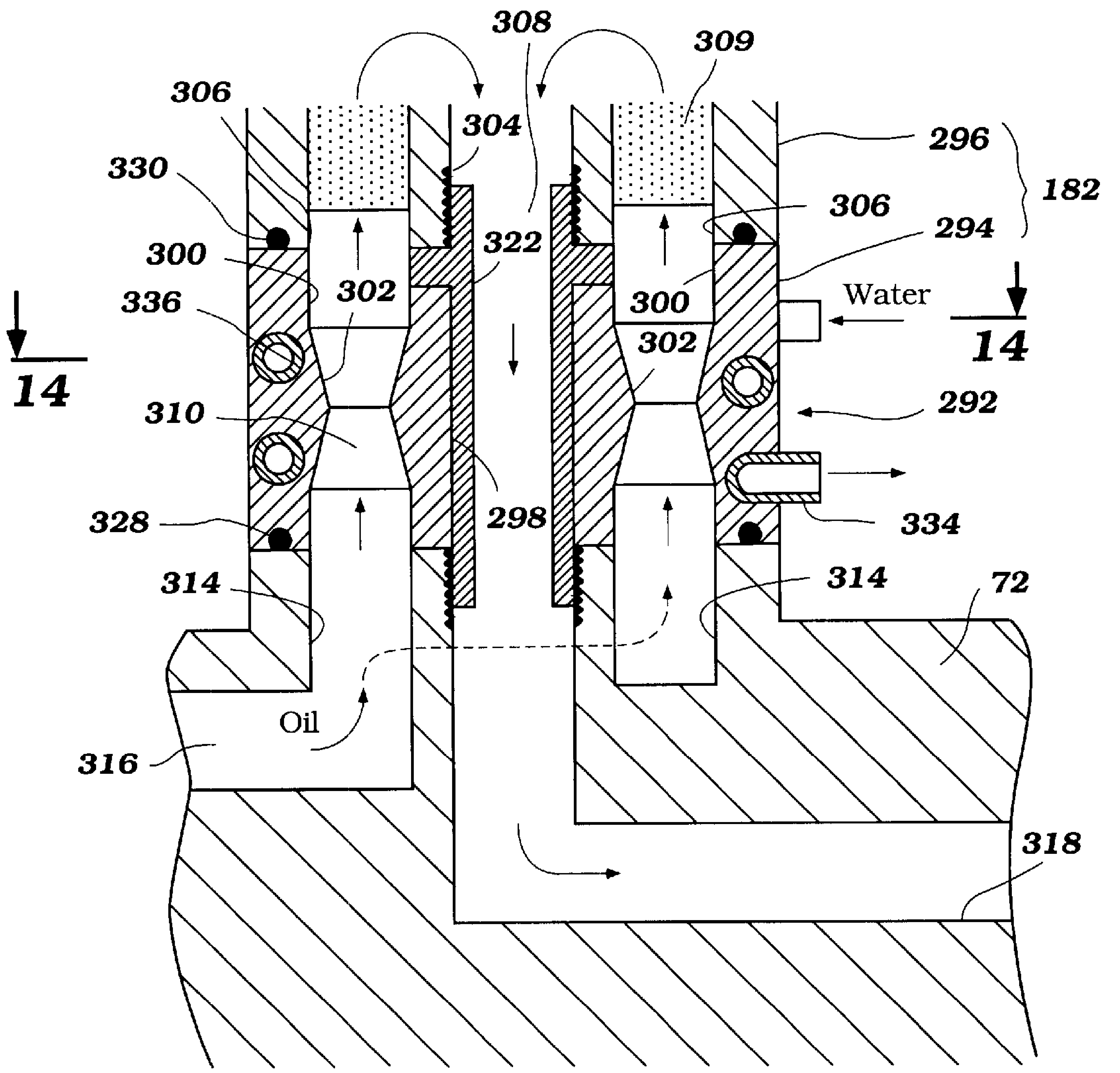

Figure 13

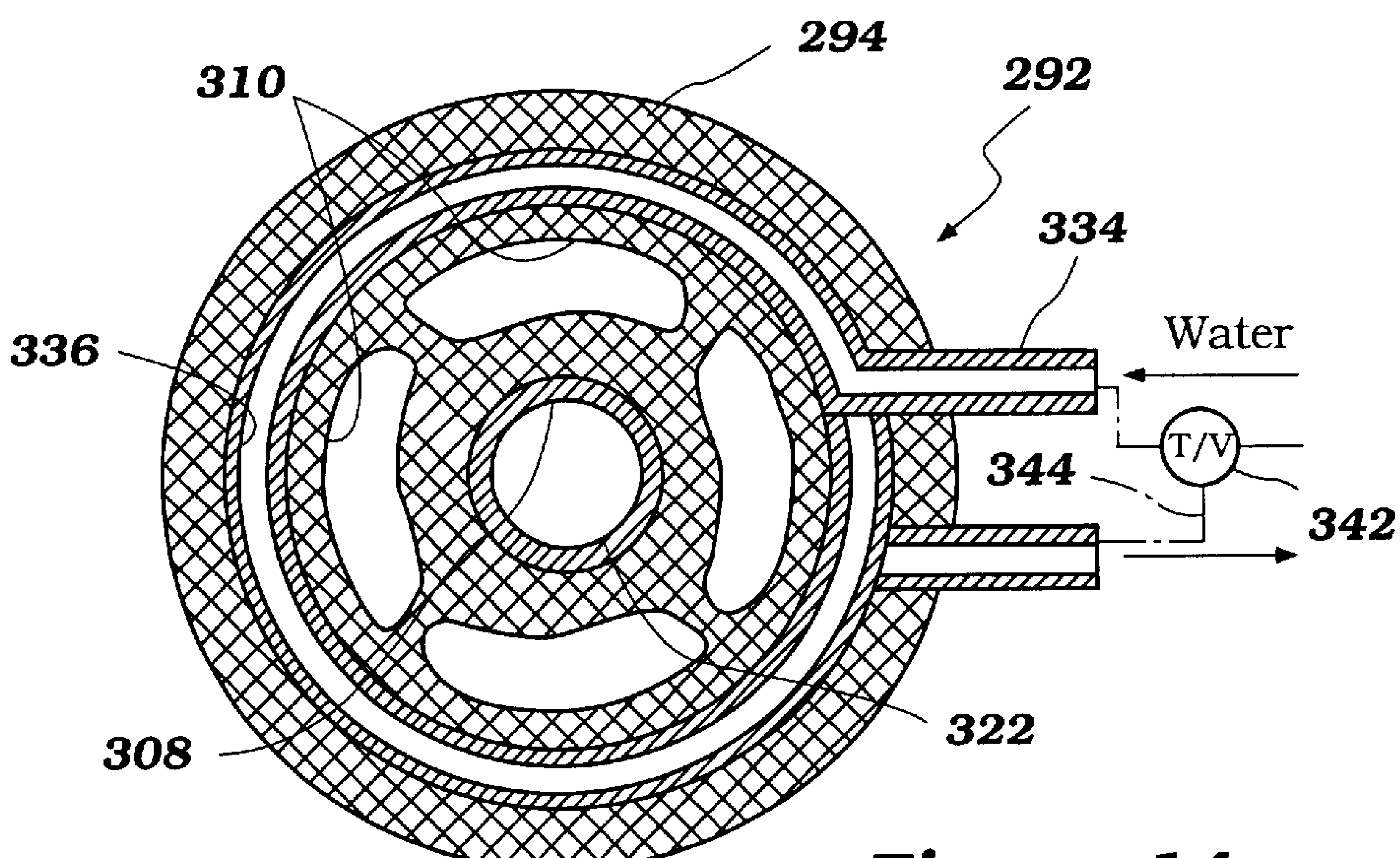

Figure 14

COOLING SYSTEM FOR OUTBOARD MOTOR

PRIORITY INFORMATION

This application is based on and claims priority to Japanese Patent Application No. 2000-074225, filed Mar. 16, 2000, the entire contents of which is hereby expressly incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a cooling system for an outboard motor. More particularly, the present invention relates to a cooling system for an engine and a plurality of engine components of an outboard motor.

2. Description of Related Art

Typically, an outboard motor comprises an engine disposed atop a drive unit of the motor. To propel the associated watercraft, the engine drives a propulsion device placed in a submerged position through a proper drive mechanism. The engine usually has an engine body and a plurality of components. The engine body normally comprises a cylinder block, a cylinder head assembly and a crankcase assembly. At least one combustion chamber, and often more than one combustion chamber, is provided within the engine. Occasionally, part of an exhaust passage is unitarily formed with the engine body. Other engine components can include, for example, air intake conduits, fuel supply conduits, lubricant delivery conduits and a power generator, which all relate to the operation of the engine.

The engine body comprising the exhaust part and the foregoing engine components usually build much heat during the engine operations. The heat can accumulate therein unless properly removed and excessive heat can jeopardize normal engine operations. Typical engines thus have a cooling system that can cool the heated portions of the engine body and engine components. Various cooling systems are practicable.

One type of cooling system introduces water from outside of the motor and cools the engine body first because the engine body is subjected to greater temperature levels when compared to peripheral engine components. The water that has cooled the engine body then flows to the respective peripheral engine components. Another type of cooling system has a direct conduit branching off upstream of the engine body to supply fresh water to a peripheral engine component.

For instance, U.S. Pat. Nos. 5,975,032 and 5,980,340 disclose the former type of cooling system, while U.S. Pat. No. 5,438,962 discloses the latter type of cooling system. Japanese Laid-Open Patent Publication No. Hei 6-42345, published on Feb. 15, 1994, also discloses a rectifier-regulator cooling structure using fuel or water flowing through a cooling passage. Furthermore, Japanese Laid-Open Patent Publication No. Hei 11-324696, published on Nov. 26, 1999, discloses a cooling system that can cool a power generator and a high pressure fuel pump. An auxiliary water supply passage branches off from a main water supply passage to the generator and then to the fuel pump. The water that has cooled these two components then is discharged through a submerged discharge port.

In engine design for outboard motors, there is an increasing emphasis on obtaining high performance in output and more effective emission control. This trend has resulted in employing, for example, a multi-cylinder, fuel injected, four-cycle engine. This type of engine must have a greater number of engine components or larger sizes thereof than those of conventional engines. The engine body and the engine components of this new type of engine also produce greater heat levels than two-stroke engines. Particularly, if the components are one-sided or if the components are disposed such that only one side is cooled, the engine can develop disadvantageous hot zones. The hot zones can result in distortion of the engine body or engine components, or disruption of proper engine operations. The forgoing conventional cooling systems are not enough to resolve this problem.

A need therefore exists for an improved cooling system for an outboard motor that can cool an engine body and engine components efficiently and that can maintain a relatively good heat balance in connection with the respective sides.

In addition, if a cooling system malfunctions such that water can no longer be supplied to the portions that need the water for cooling, the engine can overheat. Engine overheat can result in, for example, seizure of pistons and malfunction of engine components. A pilot water discharge is useful to let the operator know of cooling system abnormalities, such as plugging. U.S. Pat. No. 5,823,835 discloses such a pilot water discharge. In this arrangement, a pilot discharge port is positioned above the water line and a small amount of cooling water that has passed through cooling jackets disposed in the engine body is expelled through this pilot discharge port as visual confirmation to the operator that cooling water is being properly supplied to the engine body.

As noted above, the engine body produces heat greater than the engine components, and in addition, the heat of the recent multiple cylinder engine is higher than before. The elevated temperature of the pilot water can discolor the coating that covers a surface of the housing or cowling of the outboard motor. For instance, in the region of the port, the high temperature water can discolor the outward appearance of the motor or cause scaling and the like.

Another need thus exists for an improved cooling system that has a pilot water discharge that does not adversely affect to a large degree the outward appearance of the outboard motor.

Further, the foregoing engine components are generally formed with metal material, such as, for example, aluminum based alloy cast material as well as the engine body. Otherwise, at least part of the engine components is formed with metal material for the heat exchange purpose although the rest part of the components is made of other material such as plastic. When the motor is used on the sea, seawater, i.e., salt water, is supplied to the engine components. The salt water, however, is likely to corrode bodies of the engine components that are made of metal material and hence can damage their primary functions.

A further need therefore exists for an improved cooling system for an outboard motor that can inhibit corrosion from encroaching engine components.

SUMMARY OF THE INVENTION

Accordingly, one aspect of the present invention involves an internal combustion engine for an outboard motor comprising an engine body, at least three engine components disposed around the engine body, and a water cooling system for cooling both the engine body and the engine components. The cooling system comprises a first water passage arranged to cool the engine body and a second water passage branching off from the first water passage upstream of the engine body and extending through the at least three engine components. A first of the at least three engine components is generally positioned above the engine body while a second and a third of the at least three engine components is generally positioned on a different side of the engine body relative to one another.

Another aspect of the present invention involves an internal combustion engine comprising an engine body, a plurality of engine components disposed around the engine body, and a water cooling system for cooling both the engine body and the engine components. The cooling system comprises a first water passage arranged to cool the engine body and a second water passage branching off from the first water passage upstream of the engine body and extending through the plurality of engine components in series. The first and second water passages have separate discharge ports that are located remotely from each another and the water discharge port of the second water passage is positioned next to the engine body.

A further aspect of the present invention involves an internal combustion engine comprising an engine body, a plurality of engine components being disposed around the engine body, and a water cooling system arranged to cool both the engine body and the plurality of engine components. The cooling system comprises a first water passage arranged to cool the engine body and a second water passage branching off from the first water passage upstream of the engine body and extending through the plurality of engine components. The plurality of engine components are made of a metal material with the second water passage in part being defined by tubular members made of a corrosion-resistant material. The respective tubular members are at least partially embedded in respective bodies of the engine components.

Another aspect of the present invention involves an internal combustion engine comprising an engine body, a plurality of engine components disposed around the engine body, and a cooling system for cooling both the engine body and the plurality of engine components. The cooling system comprises a first coolant passage arranged to cool the engine body and a second coolant passage branching off from the first coolant passage upstream of the engine body and extending through at least three of the plurality of engine components. The at least three engine components comprising a first engine component positioned at least above the engine body and a two engine components each positioned on two sides of the engine body so as to be spaced apart from each other.

An additional aspect of the present invention involves an outboard motor comprising an engine body, a plurality of engine components disposed around the engine body, and a water cooling system comprising a water inlet disposed lower than the engine body so as to introduce the water into the cooling system. A first water passage is arranged to cool the engine body and a second water passage is arranged to cool the plurality of engine components. The first water passage has a first water discharge port positioned closer to the water inlet than to the engine body and the second water passage has a second water discharge port positioned closer to the engine body than to the water inlet.

Further aspects, features and advantages of this invention will become apparent from the detailed description of the preferred embodiment which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects and advantages of the present invention will now be described with reference to the drawings of a preferred embodiment which is intended to illustrate and not to limit the invention. The drawings comprise 14 figures.

FIG. **1** is a side elevational view of an outboard motor comprising a cooling system arranged in accordance with a preferred embodiment of the present invention. The cooling system is illustrated schematically in the figure and actual positioning of respective engine components and a pilot discharge port can differ from those illustrated. A watercraft associated with the outboard motor also is partially shown in section.

FIG. **2** is a top plan view showing a power head of the outboard motor. A top cowling member is detached. A portion of the engine is shown in section.

FIG. **3** is an enlarged port side view of the engine with a portion of the power head illustrated in section and with a portion of the engine being shown in section.

FIG. **4** is another enlarged starboard side view of the engine with a portion of the power head illustrated in section and with a portion of the engine being shown in section.

FIG. **5** is a cross-sectional view of an exemplary air intake conduit provided with water passages.

FIG. **6** is a schematic view of a heat exchanger and fuel rail construction.

FIG. **7** is a schematic view of a heat exchanger and fuel conduit assembly construction.

FIG. **8** is a schematic top plan view showing a stator of a flywheel magnet. For clarity, a portion of the stator is omitted in this figure.

FIG. **9** is a schematic side view of the stator of FIG. **8**.

FIG. **10** is a schematic cross-sectional view of a heat exchanger and stator bracket construction.

FIG. **11** is a top plan view showing a rectifier-regulator assembly with a heat exchange construction.

FIG. **12** is a side view of the heat exchange construction for a rectifier-regulator assembly.

FIG. **13** is a cross-sectional view of an oil filter assembly with a heat exchange construction generally taken along the line **13**—**13** of FIG. **4**.

FIG. **14** is a cross-sectional view of the oil filter assembly taken along the line **14**—**14** of FIG. **13**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

With reference to FIGS. **1**–**4**, an overall construction of an outboard motor **30**, which employs a cooling system **31** arranged in accordance with certain features, aspects and advantages of the present invention will be described. In the illustrated arrangement, the outboard motor **30** comprises a drive unit **32** and a bracket assembly **34**. The bracket assembly **34** supports the drive unit **32** on a transom **36** of an associated watercraft **38** and places a marine propulsion device in a submerged position with the watercraft **38** resting on the surface of a body of water. The bracket assembly **34** preferably comprises a swivel bracket **40**, a clamping bracket **42**, a steering shaft **44** and a pivot pin **46**.

The steering shaft **44** typically extends through the swivel bracket **40** and is affixed to the drive unit **32**. The steering shaft **44** is pivotally journaled for steering movement about a generally vertically-extending steering axis defined within the swivel bracket **40**. The clamping bracket **42** comprises a pair of bracket arms that are spaced apart from each other and that are affixed to the watercraft transom **36**. The pivot pin **46** completes a hinge coupling between the swivel bracket **40** and the clamping bracket **42**. The pivot pin **46** extends through the bracket arms so that the clamping bracket **42** supports the swivel bracket **40** for pivotal movement about a generally horizontally-extending tilt axis defined by the pivot pin **46**. The drive unit **32** thus can be tilted or trimmed about the pivot pin **46**.

As used through this description, the terms "forward," "forwardly" and "front" mean at or to the side where the bracket assembly **34** is located, and the terms "rear," "reverse," "backwardly" and "rearwardly" mean at or to the opposite side of the front side, unless indicated otherwise or otherwise readily apparent from the context use.

A hydraulic tilt and trim adjustment system preferablyis provided between the swivel bracket **40** and the clamping bracket **42** to tilt (raide or lower) the weivel bracket **40** and the drive unit **32** relative to the clamping bracket **42**. Otherwise, the outboard motor **30** can have a manually operated system for tilting the drive unit **32**. Typically, the term "tile movement", when used in a broad sense, comprises both a tilt movement and a trim adjustment movement.

The illustrated drive unit **32** comprises a power head **48**, a driveshaft housing **50** and a lower unit **52**. The power head **48** is disposed atop the drive unit **32** and comprises an internal combustion engine **54** that is positioned within a protective cowling **56**. Preferably, the protective cowling **56** defines a generally closed cavity **58** in which the engine **54** is disposed. The protective cowling **56** preferably comprises a top cowling member **60** and a bottom cowling member **62**. The top cowling member **60** is preferably detachably affixed to the bottom cowling **62** by a coupling mechanism **63** (see FIGS. **3** and **4**) so that a user, operator, mechanic or repair person can access the engine **54** for maintenance or for other purposes.

With continued reference to FIGS. **3** and **4**, the top cowling **60** preferably has at least one air intake opening **64** and at least one air duct **65** disposed on its rear and top portion. Ambient air is drawn into the closed cavity **58** from within the opening **64** through the duct **65**. Typically, the top cowling member **60** tapers in girth toward its top surface, which is in the general proximity of the air intake opening **64**.

With reference again to FIG. **1**, the bottom cowling member **62** preferably has an opening at its bottom portion through which an upper portion of an exhaust guide member **66** extends. The exhaust guide member **66** is affixed atop the driveshaft housing **50**. The bottom cowling member **62** and the exhaust guide member **66** together generally form a tray. The engine **54** is placed onto this tray and is affixed to the exhaust guide member **66**. The exhaust guide member **66** also has an exhaust passage through which burnt charges (e.g., exhaust gases) from the engine **54** are discharged as described below.

The engine **54** in the illustrated embodiment operates on a four-cycle combustion principle. With reference now to FIG. **2**, the engine **54** has a cylinder block **72**. The presently preferred cylinder block **72** defines four cylinder bores **73** which extend generally horizontally and are generally vertically spaced from one another. As used in this description, the term "horizontally" means that the subject portions, members or components extend generally in parallel to the water line where the associated watercraft is resting when the drive unit **32** is not tilted and is placed in the position shown in FIG. **1**. The term "vertically" in turn means that portions, members or components extend generally normal to those that extend horizontally. This type of engine, however, merely exemplifies one type of engine on which various aspects and features of the present invention can be suitably used. Engines having other number of cylinders, having other cylinder arrangements, and operating on other combustion principles (e.g., crankcase compression two-stroke or rotary) also can employ various features, aspects and advantages of the present invention.

A piston (not shown) reciprocates in each cylinder bore **73** in a well-known manner. A cylinder head assembly **74**, such as that illustrated in FIG. **2**, for instance, is affixed to one end of the cylinder block **72** for closing the cylinder bores **73**. The cylinder head assembly **74** preferably defines four combustion chambers together with the associated pistons and cylinder bores **73**. Of course, the number of combustion chambers can vary, as indicated above. A crankcase assembly **76** closes the other end of the cylinder bores **73** and defines a crankcase chamber together with the cylinder block **72**. A crankshaft **80** extends generally vertically through the crankcase chamber and is journaled for rotation by several bearing blocks (not shown) in a suitable arrangement. Connecting rods (not shown) couple the crankshaft **80** in a well-known manner with the respective pistons. Thus, the crankshaft **80** can be rotated by the reciprocal movement of the pistons.

Preferably, the crankcase assembly **76** is located at the most forward position, with the cylinder block **72** and the cylinder head member **74** extending rearward from the crankcase assembly **76**, one after another. Generally, the cylinder block **72**, the cylinder head member **74** and the crankcase assembly **76** together define an engine body **82**. Preferably, at least these major engine portions **72**, **74**, **76** are made of aluminum based alloy. The aluminum alloy advantageously increases strength over cast iron while decreasing the weight of the engine body **72**.

The engine **54** comprises an air induction system. The air induction system draws air to the combustion chambers from the cavity **58** of the protective cowling assembly **56**. The air induction system preferably comprises intake ports, four intake passages **84** and a plenum chamber **86**. The intake ports can be defined in the respective cylinder head members **74**. In one configuration, intake valves repeatedly open and close the respective intake ports. When each intake port is opened, the corresponding intake passage **84** communicates with the associated combustion chamber.

In the illustrated arrangement, the air intake passages **84** are defined by a pair of intake manifolds **90**, a set of throttle bodies **92** and a set of intake runners **94**, while the plenum chamber **86** is defined by a plenum chamber member **96**. The plenum chamber member **96** has an inlet port **100** opening to the closed cavity **58** to draw the air in the cavity **58** into the plenum chamber **86**. Each intake manifold **90** has a flange portion that is affixed to the cylinder head member **74**. The throttle bodies **92** are interposed between the intake manifolds **90** and the intake runners **94**. The plenum chamber **86** defined by the plenum chamber member **96** is thus coupled with the associated intake ports through the intake passages **84** defined by the intake runners **94**, the throttle bodies **92** and the intake manifolds **90**.

The intake manifolds **90** and the throttle bodies **92** preferably are made of aluminum based alloy. The intake runners **94** preferably are unitarily formed with the plenum chamber member **96** and this unitary component preferably is made of a plastic or resin-based material. In some configurations, an aluminum based alloy can be used. In either case, i.e., aluminum based alloy or plastic material, the intake manifolds **90**, the throttle bodies **92** and the combined intake runner and plenum chamber member can be produced by, for example, a conventional casting method. Of course, these intake components can be made of other materials and by other conventional manufacturing processes.

The respective throttle bodies **92** preferably have throttle valves journaled therein for pivotal movement about an axis of a valve shaft that extends generally vertically. While not shown, in the illustrated arrangement, the throttle valves advantageously are butterfly valves. The throttle valves are operable by the operator through an appropriate conventional throttle valve linkage **102** (see FIG. **3**). The throttle valves measure or regulate an amount of air flowing through the respective air intake passages **84**. In other words, the air amount is variable by changing the positions or opening degrees of the throttle valves. Normally, the greater the opening degree, the higher the rate of airflow and the higher the engine speed.

The engine **54** also comprises an exhaust system that discharges the burnt charges or exhaust gases to a location outside of the outboard motor **30**. Each cylinder bore **73** preferably has exhaust ports defined in the cylinder head assembly **74**. The exhaust ports are repeatedly opened and closed by exhaust valves.

An exhaust manifold **106** (see FIG. **2**) is defined next to the cylinder bores **73** in the cylinder block **72** and preferably extends generally vertically. The exhaust manifold **106** communicates with the exhaust ports to collect exhaust gases from the combustion chambers through the respective exhaust ports. The exhaust manifolds **106** are coupled with the exhaust passage in the exhaust guide member **66**. When the exhaust ports are opened, the combustion chambers communicate with this exhaust passage through the exhaust manifold **106**.

A valve cam mechanism is preferably provided for actuating the intake and exhaust valves. In the illustrated embodiment, the cylinder head assembly **74** journals an intake camshaft **110** and an exhaust camshaft **112**. The camshafts **110, 112** extend generally vertically and in parallel to each other. The intake camshaft **110** actuates the intake valves, while the exhaust camshaft **112** actuates the exhaust valves. The respective camshafts **110, 112** have cam lobes to push the intake and exhaust valves in a controlled timing to open and close the intake and exhaust ports. A single camshaft can replace the intake and exhaust camshafts **110, 112** in a manner that is well known. Other conventional valve drive mechanisms can be of course employed instead of such a mechanism using one or more camshafts.

A camshaft drive mechanism is provided for driving the valve cam mechanism. As seen in FIG. **2**, intake and exhaust camshafts **110, 112** have driven sprockets **114** positioned atop thereof and the crankshaft **80** has a drive sprocket **116** positioned almost atop thereof. A timing chain or belt **118** is wound around the drive and driven sprockets **116, 114**. The crankshaft **80** thus drives both the camshafts **110, 112** through the timing chain **118** in timed relationship. A tensioner **120** preferably abuts on a side of the timing chain **118** so as to give proper tension to the chain **118**. A diameter of the driven sprockets **114** preferably is twice as large as a diameter of the drive sprocket **116**. The intake and exhaust camshafts **110, 112** thus rotate at half of the speed of the rotation of the crankshaft **80**.

The engine **54** preferably has a port or manifold fuel injection system. The fuel injection system preferably comprises four fuel injectors **124** with one fuel injector allotted for each of the respective combustion chambers. Each fuel injector **124** preferably has an injection nozzle directed toward the associated intake passage **84** adjacent to the intake ports. The fuel injector **124** also preferably has a plunger that normally closes the nozzle and solenoid coil that moves the plunger from the closed position to an open position when energized with electric power. Of course, in some arrangements, the fuel injectors can be disposed for direct cylinder injection and, in other arrangements, carburetors can replace or accompany the fuel injectors.

The fuel injectors **124** spray fuel into the intake passages **84** under control of an ECU (electronic control unit). The ECU controls energizing timing and duration of the solenoid coils so that the plungers open the nozzles to spray a proper amount of the fuel into the engine **54** during each combustion cycle. A fuel rail **126** supports the fuel injectors **124** and also defines a fuel passage to the injectors **124**. The fuel rail **126** preferably extends generally vertically along a side surface of the cylinder head assembly **74** on the port side. The fuel rail **126** preferably is made of metal material such as, for example, an aluminum-based alloy, similar to the engine body **82**.

The fuel injection system further comprises a fuel supply tank that preferably is placed in the hull of the associated watercraft **38**. Fuel is drawn from the fuel tank by a first low pressure fuel pump (not shown) and a second low pressure pump **128** (see FIG. **3**) through a fuel supply conduit. The first low pressure pump preferably is a manually operated pump. The second low pressure pump **128** preferably is a diaphragm-type pump that can be operated by, for example, the intake or exhaust camshaft **110, 112**. In this instance, the second low pressure pump **128** is mounted on the cylinder head assembly **74**. A quick disconnect coupling can be provided in the supply conduit. Also, a fuel filter **130** can be positioned in the supply conduit at an appropriate location. The fuel filter **130** is preferably mounted on the cylinder head assembly **74**.

From the second low pressure pump **128**, the fuel enters a vapor separator **134** from the fuel supply conduit. In the illustrated arrangement, the vapor separator **134** is disposed in a space defined between the port side surface of the engine body **82** and the intake manifolds **90** and the vapor separator is advantageously mounted on the cylinder block **72**. At the vapor separator end of the supply conduit, a float valve can be provided that is operated by a float to maintain a substantially uniform level of the fuel within the vapor separator **134**.

A high pressure fuel pump preferably is provided in the vapor separator **134**. The high pressure fuel pump pressurizes fuel that is delivered through a delivery conduit to the fuel injectors **124** on the fuel rail **126**. The high pressure fuel pump in the illustrated arrangement preferably comprises a positive displacement pump. The construction of the pump thus generally inhibits fuel flow from its upstream side back into the vapor separator **134** when the pump is not running. A back-flow prevention device (e.g., a check valve) also can be used to prevent a flow of fuel from the delivery conduit back into the vapor separator **134** when the pump is off. This later approach can be used with a fuel pump that employs a rotary impeller to inhibit a drop in pressure within the delivery conduit when the pump is intermittently stopped. An electric motor preferably drives the high pressure fuel pump. The electric motor is preferably unified with the high pressure pump at its bottom portion and hence is disposed in the vapor separator **134**.

Excess fuel that is not injected by the injector **124** returns to the vapor separator **134** through a return conduit. A pressure regulator **138** preferably is positioned at the most upstream portion of the return conduit, i.e., atop the fuel rail **126**. The pressure regulator **138** limits fuel pressure to keep it at a fairly constant level at all times.

A desired amount of the fuel is sprayed into the intake passages **84** through the injection nozzles at a selected timing for a selected duration. The timing and duration preferably are controlled by the ECU. Because the pressure regulator **138** controls and stabilizes the fuel pressure, the duration can be used to determine a selected amount of fuel that will be supplied to the combustion chambers. Various control strategies for the injection timing and injection duration can be applied so that the optimum engine operation or an operation near to the optimum operation will be realized.

The fuel injection system will be described further in connection with the cooling system **31** later.

The engine **54** further comprises an ignition or firing system. Each combustion chamber is provided with a spark plug connected to the ECU so that ignition timing is also controlled by the ECU. The spark plugs have electrodes that are exposed into the associated combustion chamber and that ignite an air/fuel charge in the combustion chamber at selected ignition timing. The ignition system preferably has an ignition coil and an igniter which are disposed between the spark plugs and the ECU. In order to enhance or maintain engine performance, the ignition timing can be advanced or delayed in response to various engine running conditions.

The ignition coil preferably is a combination of a primary coil element and a secondary coil element that are wound around a common core. Desirably, the secondary coil element is connected to the spark plugs, while the primary coil element is connected to the igniter. Also, the primary coil element is coupled with a power source so that electrical current flows therethrough. The igniter abruptly cuts off the current flow in response to an ignition timing control signal from the ECU and then a high voltage current flow occurs in the secondary coil element. The high voltage current flow forms a spark at each spark plug.

In the illustrated engine **54**, the pistons reciprocate between top dead center and bottom dead center. When the crankshaft **80** makes two rotations, the pistons generally move from top dead center to bottom dead center (the intake stroke), from bottom dead center to top dead center (the compression stroke), from top dead center to bottom dead center (the power stroke) and from bottom dead center to top dead center (the exhaust stroke). During the four strokes of the pistons, the respective camshafts **110, 112** make one rotation. The intake camshaft **110** actuates the intake valves to open the intake ports during the intake stroke, while the exhaust camshaft **112** actuates the exhaust valves to open the exhaust ports during the exhaust stroke.

Generally, at the beginning of the intake stroke, air preferably is drawn through the air intake passages **84** and fuel preferably is injected into the intake passage **84** by the fuel injectors **124**. The air and the fuel thus are mixed to form the air/fuel charge in the combustion chambers. Just before or during the power stroke, the respective spark plugs ignite the compressed air/fuel charge in the respective combustion chambers. The engine **54** thus continuously repeats the foregoing four strokes during its operation.

As discussed above, during engine operation, heat builds in the engine body **82**, i.e., the cylinder block **72**, the cylinder head assembly **74**, the exhaust manifold **106** and various peripheral engine components disposed around the engine body **82**. The cooling system **31** thus is provided to help cool such engine portions and engine components.

With regard to the engine body **82**, one or more water jackets preferably are provided that extend through or alongside portions of the engine body so that circulating cooling water can remove at least some of the heat accumulating in the engine portions. In the illustrated open loop cooling system, the cooling water is drawn into the cooling system **31** through a water inlet **143** from the body of water surrounding the outboard motor **30** by a water pump **144**. The water inlet **143** is disposed in a portion of the lower unit **52** that preferably is positioned under the water line at a level that will generally remain submerged when the drive unit **32** is fully or almost fully tilted down. The water pump **144**, in turn, is disposed in the driveshaft housing **50**.

The water is pressurized toward the water jackets provided to the engine body **82** through a water supply conduit **146** and then travels through the respective water jacket or water jackets. The water that has cooled the engine portions then goes through a discharge conduit **148** (see FIG. 2) before being discharged through one or more internal portions of the driveshaft housing **50**. A thermostat **150** preferably is placed along a portion of the cooling system and, more preferably, is placed at the most upstream end of the discharge conduit **148**. In this location, the thermostat **150** advantageously reduces or stops a cooling water flow that passes through the discharge conduit **148** until the engine body **54** is warmed up to a preset temperature. Such an arrangement advantageously increases engine warm-up even under cold conditions.

The engine **54** also comprises a closed-loop type lubrication system. The lubrication system comprises a lubricant oil reservoir **154** preferably positioned within the driveshaft housing **50**. An oil pump **156** is provided at a desired location, such as atop the driveshaft housing **50**, to pressurize the oil in the reservoir **154** and to pass the oil toward engine portions, which are desirably lubricated, through lubricant delivery passages. The engine portions that should be lubricated include, for instance, the crankshaft bearings, the connecting rods and the pistons. Lubricant return passages also are provided to return the oil to the oil reservoir **154** for re-circulation. Preferably, the lubrication system further comprises a filter assembly **182** that is mounted on a starboard side surface of the cylinder block **72** to remove foreign matter from the oil (e.g., metal shavings, dirt, dust and water) before the oil is recirculated or delivered to the various engine portions.

A flywheel assembly **160** preferably is positioned above the engine body **82**. The illustrated flywheel assembly **160** comprises a flywheel magneto or AC generator **162** that supplies electric power to various electrical components, comprising the fuel injection system, the ignition system and the ECU. The flywheel magneto **162** generally comprises a rotor **164** and a stator **166** and can be constructed in any suitable manner.

In the illustrated arrangement, the rotor **164** is positioned atop the crankshaft **80** and is mounted for rotation with the crankshaft **80**. Preferably, the rotor **164** is configured as an overturned cup shape and is made of cast iron or another suitable material such that it has a relatively large mass. The large mass is desired, eventhough it is positioned at the top end of the outboard motor, because the rotor **164** concurrently acts as a flywheel to smooth rotation of the engine. A plurality of magnets **168** is affixed to the inner side surface of the rotor **164**. The magnets **168** are juxtaposed with each other but are spaced apart from one another to form gaps between the magnets **168**.

The stator **166** is affixed to a ring-shaped bracket **172** that is mounted on the engine body **82**. The stator **166** comprises a plurality of electrical coils **174** facing the magnets **168** on the rotor **164**. When the rotor **164** rotates around the stator **166**, the magnets **168** intermittently pass the electrical coils **174**. Electric power is induced in the coils to generate electric power (i.e., AC power) by a well-known electromagnetic induction effect. The generated AC power preferably is rectified and is regulated by a rectifier-regulator and then is accumulated in a battery so that the electrical components comprising the fuel injection system, ignition system and ECU can use DC power. The battery is preferably placed in the hull of the watercraft **38**.

The flywheel assembly **160** also comprises a ring gear **178** that extends around an outer surface of the illustrated flywheel assembly **160**. A starter motor (not shown) preferably drives the crankshaft **80** to start the engine **54**. The starter motor has a gear portion that meshes with the ring gear **178**. To start the engine **54**, the starter motor drives the crankshaft **80** through the gear connection. Once the engine **54** starts, the starter motor immediately preferably is disengaged to reduce the likelihood that the starter mechanism will be damaged.

A protective cover **180** is detachably mounted atop the engine body **82** to extend over at least a portion of the flywheel assembly **160** and the camshaft drive mechanism. The protective cover **180** is useful to protect the flywheel assembly **160** and the drive mechanism which include the moving parts described above when the top cowling **60** is detached.

As seen in FIG. **1**, the driveshaft housing **50** depends from the power head **48** and supports a driveshaft **184** which is driven by the crankshaft **80**. The driveshaft **184** extends generally vertically through the driveshaft housing **50**. The driveshaft **184** preferably drives the water pump **144** and the oil pump **156**. The driveshaft housing **50** also defines internal passages which form portions of the exhaust system. An apron **185** covers an upper portion of the driveshaft housing **50** and improves the overall appearance of the outboard motor.

The lower unit **52** depends from the driveshaft housing **50** and supports a propulsion shaft **186**, which is driven by the driveshaft **184**. The propulsion shaft **186** extends generally horizontally through the lower unit **52**. A propulsion device is attached to the propulsion shaft **186** and is powered through the propulsion shaft **186**. In the illustrated arrangement, the propulsion device is a propeller **188** that is affixed to an outer end of the propulsion shaft **186**. The propulsion device, however, can take the form of a dual counterrotating system, a hydrodynamic jet, or any of a number of other suitable propulsion devices.

A transmission **192** preferably is provided between the driveshaft **184** and the propulsion shaft **186**. The transmission **192** couples together the two shafts **184, 186** which lie generally normal to each other (i.e., at a 90° shaft angle) with bevel gears. The outboard motor **30** has a switchover or clutch mechanism that allows the transmission **192** to change the rotational direction of the propeller **180** among forward, neutral or reverse.

The lower unit **52** also defines an internal passage that forms a discharge section of the exhaust system. At engine speeds above idle, the exhaust gases generally are discharged to the body of water surrounding the outboard motor **30** through the internal passage and finally through an outlet passage defined through the hub of the propeller **180**. Of course, an above-the-water discharge can be provided for lower speed engine operation. The difference in the locations of the discharges accounts for the differences in pressure at locations above the waterline and below the waterline. Because the opening above the line is smaller, pressure develops within the lower unit **52**. When the pressure exceeds the higher pressure found below the waterline, the exhaust gases exit through the hub of the propeller. If the pressure remains below the pressure found below the waterline, the exhaust gases exit through the smaller opening above the waterline.

The water that is discharged into the driveshaft housing **50** after cooling the engine preferably is used to cool the internal passages of the driveshaft housing **50** and the lower unit **52**. In one configuration, the water is collected in a portion of the lower unit **52** and then is discharged to the body of water through a discharge port (not shown) or through the hub of the propeller **180** along with the exhaust gases.

With continued reference to FIGS. **1–4** and with additionally reference to FIGS. **5–14**, the cooling system **31** will now be described in greater detail below. As described above, the cooling system **31** generally comprises the water inlet **143** through which cooling water is introduced into the water supply conduit **146**, the water pump **144** pressurizing the water to the supply conduit **146**, a set of one or more water jackets extending alongside or through the engine body **82** and the discharge conduit **148** discharging the water after it has passed through the water jackets. In the illustrated arrangement, the cooling system **31** comprises another route through which the water is provided for cooling the peripheral engine components.

As used through this description, the term "peripheral engine components" or simply "engine component(s)" means all systems, apparatus, devices, accessories, conduits, components, members, elements and other things that are disposed externally around the engine body in connection with engine operations. The definition will be clearer in the context of the following descriptions regarding exemplary configurations.

As schematically shown in FIG. **1**, the water supply conduit **146** branches off in two directions at a water pool **210** disposed within the engine body **82**. A first branch passage **212** is directed to the water jackets of the engine body **82**, while a second branch passage **214** is directed to the engine components. As best seen in FIGS. **2** and **4**, the water pool **210** preferably is disposed next to the exhaust manifold **106** at a lower portion of the cylinder block **72** on the starboard side. In the illustrated arrangement, the water pool **210** is formed within a recess defined at an outer surface of the cylinder block **72** and another recess defined at an inner surface of a cover member **216** which is affixed to the outer surface of the cylinder block **72**. Of course, other configurations also are possible. The first branch passage **212** desirably is one of the water jackets formed through the cylinder block **72** while the second branch passage **214** preferably comprises several external conduits **218***a,* **218***b,* **218***c,* **218***d,* **218***e,* **218***f* and a number of internal conduits defined within the respective engine components.

As best seen in FIG. **2**, in the illustrated arrangement, the external conduit **218***a* is coupled with the water pool **210** at an outlet port **222** thereof and then extends generally along a lower profile of the cylinder head assembly **74**, i.e., extends rearwardly, transversely and then forwardly to the port side of the engine body **82**. As seen in FIG. **3**, the illustrated conduit **218***a* then bifurcates at the lowermost portion of the cylinder head assembly **74** on the port side to form the external conduit **218***b* and the conduit **218***c*.

The external conduit **218***b* then goes up toward the intake manifolds **90**, which define a first group of the engine components that need cooling. Advantageously, cooling the intake manifolds can increase engine efficiency. The external conduit **218***b* is coupled with a passage portion **224** defined in a body of the lowermost manifold **90** and extending generally vertically therethrough. The other manifolds **90** also have similar passage portions **224**. Conduit portion **226**, which has through-holes, couples with the respective passage portions **224**. Preferably, the conduit portions **226** are unitarily formed with the manifolds **90** during casting of the manifolds **90**.

Both the passage portions **224** and the conduit portions **226** thus are basically made of an unlined aluminum based alloy as well as the manifolds **90** themselves. However, it is anticipated that the illustrated outboard motor **30** is often used on the ocean and seawater, i.e., salt water, therefore will frequently flow through the passage portions **224** and the conduit portions **226**. Because salt water can corrode the aluminum alloy, an inner pipe member or tubular member made of brass preferably is embedded in the mold at desired locations before the manifolds are cast to form an protective internal water passage **230** that extends along at least a portion of, and preferably the entire, length of the passage portions **224** and the conduit portions **226**. This construction of the passage portions **224** and the conduit portions **226**, lined or unlined, forms a heat exchange construction or arrangement **232** that is formed in connection with the intake manifolds **90**.

In this beat exchange construction **232**, the water coming from the water pool **210** flows upwardly through the internal water passage **230** to remove at least some of the heat accumulating in the intake manifolds **90**. This heat exchange construction **232** is advantageous because the air cooled by this construction **232** increases the charging efficiency. In other words, higher temperature are is less dense than lower temperature air. Accordingly, the decreasing the temperature of the intake air, more air can be drawn into the combustion chambers to provide a better air to fuel ratio for more complete combustion or to provide more air, which can be mixed with more fuel to increase the power generated during combustion.

FIG. **5** illustrates another exemplary heat exchange construction for the intake manifolds **90**. In this arrangement, each intake manifold **90** comprises the intake passage **84** through which air passes. Each manifold **90** also has a flange portion **235** at which the manifold **90** is affixed to the cylinder head assembly **74**. In the illustrated construction, the intake manifolds **90** have a pair of internal water passages **230**. The external conduit **218***b* branches off toward the respective water passages **230** under the lowermost manifold **90** and then merges together above the uppermost manifold **90**. A pair of inner pipe members **232** is embedded is a manner similar to that described above. It should be noted that the number of pipe members can vary and three or more internal water passages are, of course, practicable.

In another arrangement, the fuel rail **126** is another engine component that can be cooled. Cooling the fuel rail is advantageous because, except under very cold conditions, the fuel passing through the fuel rail **126** generally should not be heated or warmed by engine heat. Such heating can cause the fuel to vaporize or can otherwise decrease the density of the fuel. Thus, in the illustrated arrangement, the other external conduit **218***c* extends upward and is coupled to the fuel rail **126**, as best seen in FIG. **6**. The fuel rail **126** preferably has a heat exchange construction or arrangement **236** in which an internal fuel passage **238** and an internal water passage **240** extend generally parallel to each other. The fuel passage **238** has four branches connected to the respective fuel injectors **124** that are supported by the fuel rail **126**. The external conduit **218***c* is coupled with the bottom end of the internal water passage **240**. In some arrangements, the fuel rail **126** could be completely or substantially completely jacketed.

Because the fuel rail **126** is formed with aluminum based alloy as noted above, an inner pipe member **242** made of brass preferably is embedded in the fuel rail body in a casting process of the fuel rail **126** to define a protected internal water passage **240**. In the illustrated arrangement, the fuel passage **238** also is defined by an inner pipe member **244** which is made of brass and embedded in the same manner. It should be noted that the inner pipe member **244** can be made of other metal material than the brass because no seawater passes therethrough. However, to reduce differential thermal expansion concerns, it is currently preferred that the two pipe members **242**, **244** be formed of similar materials.

This heat exchange construction **236** is advantageous because possible vapor lock and/or deposit that may be formed at the nozzle portions of the fuel injectors **124** can be obviated. In addition, the accuracy of the fuel injection amount can be improved by cooling the fuel to a preset temperature range and maintaining the fuel temperature in this general range. It is anticipated that heat exchange constructions also can be disposed along the fuel supply system at other locations, i.e., components other than the fuel rail **126** such as a fuel supply conduit and/or a delivery conduit.

With reference now to FIG. **7**, another engine component that can have a exchange construction **250** is illustrated. In this arrangement, a cast block **252** made of aluminum based alloy replaces the fuel rail **126**. Inner pipe members **254**, **256** are embedded in the block **252** and extend generally parallel to each another to form the water passage **236** and the fuel passage **240**. Each pipe member **254**, **256** preferably has a main portion and inlet and outlet portions. A diameter of the main portion desirably is greater than each diameter of the inlet and outlet portions. The inlet and outlet portions extend beyond both ends of the block **252**. Outer pipes **258**, **260**, **262**, **264**, which are preferably made of elastic material such as, for example, plastic or rubber, are fitted to the respective ends of the inlet and outlet portions so as to form each part of the cooling water conduit and the fuel supply or delivery conduit. This arrangement also is effective in controlling the temperature of the fuel supply.

With reference again to FIG. **3**, the external conduits **218***b*, **218***c* merge together above the uppermost intake manifold **90** to form a single external conduit **218***d*. The external conduit **218***d* then extends forwardly along a top end of the cylinder block **72** toward the stator **166** of the flywheel magneto **162** defined in the flywheel assembly **160**. The stator **166** is a third engine component that can be cooled. The electrical coils **174** build heat that can be removed through a suitable heat exchange construction. Because the stator **166** is compactly arranged, a heat exchange construction **268** for the stator **166** preferably is provided at the ring-shaped bracket **172**.

As noted above and best seen in FIGS. **8–10**, the stator **166** preferably is affixed to the ring-shaped bracket **172** by bolts or other fasteners and the electrical coils **174** are placed radially and side by side around the stator **166**. The stator **166** and the ring-shaped bracket **172** desirably are made of metal such as, for example, aluminum based alloy. The heat produced by the coils **174** thus is conducted to the ring-shaped bracket **172** through the stator body. The ring-shaped bracket **172** has a flange **270** projecting from a bottom periphery of the bracket **172**. The ring-shaped bracket **172** preferably is affixed to a top surface of the cylinder block **72** at this flange **270** by bolts or other fasteners. Four bolt or fastener holes **274** are provided in this arrangement, but other fastening arrangements also can be used.

A pipe member **276**, preferably made of brass, desirably is embedded within the bracket **172** in a casting process of the bracket **172** to define an internal water passage **272** extending circularly along the outer periphery of the flange **270** and under the coils **174**. Both ends of the pipe member **274** extend outwardly beyond an end surface of the bracket **172** and the foregoing external conduit **218***d* is coupled to one of the ends of the pipe member **274** placed on the port side as best seen in FIG. **2**. Of course, the pipe member **274** can be attached to the cooling system in other manners, such as internally extending fittings and the like. An inlet port of the pipe member **274** is defined at the end coupled to the external conduit **218***d*. The other end of the pipe member **274**, which defines an outlet port, is placed on the starboard side as seen FIG. **2**. Of course, other configurations also can be used.

The cooling water which enters the internal water passage **272** through the inlet port from the external conduit **218***d* passes all the way through the passage **272** and then goes to the outlet port. During this movement, the water absorbs some of the heat accumulated in the bracket **172** that has been conducted from the coils **174** through the stator **166**. In this arrangement, because the heat exchange construction **268** is formed with such a simple water passage **272** defined in the ring-shaped bracket **172**, the cooling water advantageously continues flow and generally will not stagnate along any portion of the passage **272**, In other words, the rapid movement of the cooling water helps reduce the heat build up that may occur within the stator bracket **182**. Similar to the engine components described above, the water, even if it is seawater, advantageously does not easily corrode the ring-shaped bracket **172** because the pipe member **276** is formed of brass and the pipe member **276** covers the internal water passage **272** so as to protect the bracket body from the seawater.

With reference now to FIGS. **11** and **12**, a further engine component that has another heat exchange construction **280** is illustrated therein. The component in this alternative is a rectifier-regulator **282**. The rectifier-regulator **282** rectifies the AC power which is generated by the flywheel magneto **162** to DC power and also regulates the power under a preset voltage. The rectification and regulation is accompanied with production of heat and thus should be cooled in an appropriate manner.

The rectifier-regulator **282** typically is confined within a metallic container **284** and spaces remaining around electric circuit elements are preferably filled with resin or plastic material. A heat exchange block **286** made of aluminum based alloy is preferably attached to a surface of the container **284**. In the illustrated arrangement, a U-configured pipe member **288** which is made of brass is embedded within the block **286**, preferably when the block is form in a casting process, to define an internal water passage **290**. Like the inlet and outlet ports of the ring-shaped bracket **172**, one of the external conduits extending around the engine body **82** can be coupled to these ports to let the cooling water flow through the water passage **290**. The brass pipe member **288** also protects the block **286** from the corrosion of the seawater. A bolt or other fastener connection, such as adhesives, can be used to couple the block **286** with the container **284** of the rectifier-regulator **282**.

With reference again to the stator **166** and the ring-shaped bracket **172**, the external conduit **218***e* is connected to the outlet port of the bracket **172**, which is formed with the end portion of the pipe member **276**. As best seen in FIG. **4**, the external conduit **218***e* then extends downwardly along a side surface of the cylinder block on the starboard side to the oil filter assembly **182**. The filter assembly **182** is yet another engine component that can be cooled by the cooling system **31**. This is because, if the oil accumulates heat, its viscosity decreases and hence lubrication performance can deteriorate. Another heat exchange construction **292** thus is provided for the oil filter assembly **182**.

With reference to FIG. **13**, the filter assembly **182** comprises a base member **294** and a filter member **296**. The base member **294** preferably is made of a cast aluminum-based alloy like the foregoing engine components. The base member **294** thus defines a downstream portion **298** that is disposed generally on the center axis of the base member **294** and a plurality of upstream portions **300** disposed around the downstream portion **298**. The respective portions **298**, **300** preferably extend generally horizontally. Each upstream portion **300** advantageously is configured to have a tapered or narrow part **302**, which increases the flow rate in that region.

The filter member **296** also defines a downstream portion **304** that communicates with the downstream portion **298** of the base member **294** and a plurality of upstream portions **306** that communicate with the upstream portions **306**. The respective portions **304**, **306** preferably also extend generally horizontally. The downstream portions **298**, **304** together define a downstream oil passage **308** while the upstream portions **302**, **306** together define an upstream oil passages **310**. The downstream and upstream oil passages **308**, **310** communicate with one another. A single filter element **309** can be disposed in the communicating portion. That is, both the passages **308**, **310** are coupled with each other through the filter element **309**.

The upstream oil passages **300** communicate with oil supply galleries **314** defined within the cylinder block **72** and merge with each other further upstream to form a single oil supply gallery **316**. The downstream oil passage **308** is connected to a delivery oil gallery **318** defined also within the cylinder block **72**. The oil supply gallery **316** thus communicates with the oil delivery gallery **318** through the upstream and downstream oil passages **310**, **308** via the oil filter element **309**.

A coupling member **322** couples the cylinder block **72**, the base member **294** and the filter member **296** together. The illustrated coupling member **322** is generally cylindrically configured and has a flange **324**. Both outer ends of the illustrated coupling member **322** are threaded. Because the end of the delivery gallery **318** where the downstream passage **308** is connected and the end of the downstream portion **304** of the filter member **296** are also threaded, and in addition, an outer diameter of the coupling member **322** generally equal to an inner diameter of the downstream oil passage **308**, the coupling member **322** connects itself to both the cylinder block **72** and to the filter member **296**. Of course, other methods of coupling also can be used. However, the illustrated arrangement is advantageously simple and secure.

In a preferred arrangement, the coupling member **322** is first coupled to the cylinder block **72** by connecting the base member **294** with the flange **324** and then the filter member **296** is coupled to the coupling member **322**. Because of this coupling construction, the filter assembly **182** is detachable as a unit from the cylinder block **72**. Of course, in some configurations, the filter member **296** can be formed for removal separate from the filter assembly **182**. In order to inhibit oil flowing through the passages from leaking out, an O-ring or seal member **328** is preferably inserted between the cylinder block **72** and the base member **294**, and another O-ring or seal member **328** is also preferably inserted between the base member **294** and the filter member **296**.

Oil is thus provided to the engine portions that need lubrication through the supply gallery **316**, the upstream passage **310**, the filter element **309**, the downstream passage **30** and the delivery gallery **318**. As noted above, heat accumulated in the oil is removed at the filter assembly **182** in this embodiment. Thus, the illustrated filter assembly arrangement can improve the life of the lubricant used in the illustrated engine and can improve performance of the lubrication system.

An inner pipe member **334**, which advantageously can be made of brass, preferably is embedded within the base member **294** in a casting process thereof to define an internal water passage **336**. The pipe member **334** in this construction preferably is configured spirally around the upstream portions **300** of the oil passages **310**. Both ends of the pipe member **334** extend outwardly beyond an end surface of the base member **334** and the foregoing external conduit **218***e* is coupled to one of the ends of the pipe member **334** placed next to a side surface of the cylinder block **72**. Of course, other coupling arrangements also can be used. In the illustrated arrangement, however, one end is thus an inlet port of the pipe member **334**. The other end of the pipe member **334**, which defines an outlet port, is placed outside of the inlet port relative to the cylinder block **72**.

Cooling water comes in through the inlet port and flows all the way through the internal water passage **336** defined by the spiral pipe member **334**. While traversing the passage **336**, the water removes some of the heat accumulating in the base member **294** and also in the oil passing through the upstream portions **300** of the upstream oil passages. This is advantageous because the viscosity of the oil can be held under an appropriate condition. Like the foregoing engine components, the water, even if it is seawater, does not substantially corrode the base member **294** because the brass pipe member **334** protects the base member **294** from the seawater.

If the base member **294** does not accumulate heat immediately after the engine **54** has started up, the cooling water is preferably inhibited from flowing therethrough because oil should be warmed up rather than cooled down. FIG. **14** illustrates in phantom an additional arrangement that allows the oil to be suitably heated prior to cooling and maintaining a desired temperature range. Specifically, a three-direction thermo-valve **342** is preferably provided upstream the inlet port with a bypass water passage **344** branching off from the valve **342** and being directly connected to the outlet port in this arrangement. If the temperature of the water is lower than a preset temperature, the valve **342** allows the water to flow through the bypass passage **344** such that the internal water passage **336** is bypassed. If the temperature has reached a preset temperature, the valve allows the water to flow the internal water passage **336** and the temperature of the oil can be controlled.

As best seen in FIGS. **2** and **4**, the external conduit **218***f* preferably is connected to the outlet port of the pipe member **334** and desirably extends generally along a lower profile of the cylinder head assembly **74** together with, and generally parallel to, the external conduit **218***a*. The bottom cowling member **62** preferably has a pilot discharge port **346** at a corner on the rear starboard side. A nipple preferably extends toward the internal cavity **58** of the cowling assembly **56** from the discharge port **346** and the end of the external conduit **218***f* is fitted onto the nipple. The pilot discharge port **346** thus is positioned closer to the engine body **82** than to the water inlet port **143**. To the contrary, the propeller hub, through which the water that has cooled the engine body **82** flows, desirably is positioned closer to the water inlet port **143** than to the engine body **82**.

In the illustrated arrangement, all the water that has traveled around the engine components will be discharged through the pilot discharge port **346**. The pilot discharge port can be defined in an upper area of the driveshaft housing. The water discharge thus is visible by the watercraft operator. This is advantageous because the operator can recognize that at least this portion of the cooling system **31** is functioning as expected because of the visual confirmation of the water discharge. The water passing through the engine components is not as hot as the water passing through the engine body **82** itself because the engine components themselves do not produce the same level of heat and most only absorb heat conducted from the engine body **82**. Thus, this pilot discharge has a reduced temperature that is less likely to deteriorate coatings on the drive unit **32** and hence the neat appearance of the outboard motor **30** can be kept accordingly.

As described above, in the illustrated embodiment, the first water passage supplies water cooling the engine body, while the second water passage branches off from the first water passage upstream the engine body and supplies water cooling the engine components in series. One of the engine components, i.e., the stator, is positioned above the engine body and two other components, i.e., the intake manifolds (or the fuel rail) and the oil filter assembly, preferably are positioned on different sides of the engine body, i. e., on the port side and the starboard side, respectively. The cooling system thus can cool the engine body and the engine components efficiently and can hold good heat balance in connection with the respective sides.

In addition, the water is unlikely to stagnate because of the arrangement connecting the respective component in series. However, it is anticipated that the arrangement also can employ either entire or partial parallel connections. For instance, if two or more components extend in parallel or these components have generally the same heat level, then the cooling system can have connections arranged in parallel. Preferably, an engine component that can produce or accumulate heat causing an operating temperature greater than the operating temperature of another component is placed downstream of the other component. Thus, the cooler components should be cooled first. Of course, this is a mere guideline and other arrangements or layouts can be practicable if arrangements complying with the guideline are too complicated or the lengthy.

The engine components described above preferably have bodies made of aluminum-based alloy and the pipe members, which preferably are made of brass, are embedded within the bodies because the aluminum alloy has the excellent heat transfer rate and the brass has the good anti-corrosion nature. Other metal materials, however, also can be used. For example, a copper-based alloy, which has also a good heat transfer rate, can replace the aluminum-based alloy. In addition, stainless pipe members can replace the brass pipe members because stainless steel is less likely to be corroded by seawater. In fact, particular types of stainless steel can be selected based upon their projected durability.

Of course, the foregoing description is that of a several preferred construction having certain features, aspects and advantages in accordance with the present invention. In addition, not all of the above-described components must be used in a single cooling system and a cooling system can employ various components without employing other components. Thus, various changes and modifications may be made to the abovedescribed arrangements without departing from the spirit and scope of the invention, as defined by the appended claims.

What is claimed is:

1. An internal combustion engine comprising an engine body, a plurality of engine components disposed around the engine body, and a water cooling system for cooling both the engine body and the engine components, the cooling system comprising a first water passage arranged to cool the engine body, and a second water passage branching off from the first water passage upstream of the engine body and extending through the plurality of engine components in series, the first and second water passages comprising separate discharge ports that are located remotely from each other, and the discharge port of the second water passage being positioned next to the engine body.

2. The engine as set forth in claim **1**, wherein the plurality of engine components are made of a metal material, the second water passage being at least partially defined by tubular members made of a corrosion-resistant material, and the respective tubular members being embedded in respective bodies of the plurality of engine components.

3. The engine as set forth in claim **1**, wherein the second water passage terminates at a discharge port that extends through an outer surface of an upper portion of the outboard motor.

4. An internal combustion engine comprising an engine body, a plurality of engine components being disposed around the engine body, and a water cooling system arranged to cool both the engine body and the plurality of engine components, the cooling system comprising a first water passage arranged to cool the engine body and a second water passage branching off from the first water passage upstream of the engine body and extending through the plurality of engine components, the plurality of engine components being made of a metal material, the second water passage in part being defined by tubular members made of a corrosion-resistant material and the respective tubular members being at least partially embedded in respective bodies of the engine components.

5. The engine as set forth in claim **4**, wherein the second water passage terminates at a discharge port that extends through an outer surface of an upper portion of the outboard motor.

6. An internal combustion engine comprising an engine body, a plurality of engine components disposed around the engine body, and a cooling system for cooling both the engine body and the plurality of engine components, the cooling system comprising a first coolant passage arranged to cool the engine body, and a second coolant passage branching off from the first coolant passage upstream of the engine body and extending through at least three of the plurality of engine components, the three engine components comprising a first engine component positioned at least above the engine body, and a second engine component and a third engine component each positioned on a different side of the engine body so as to be spaced apart from each other.

7. The internal combustion engine as set forth in claim **6**, wherein the second coolant passage is coupled with the first, second and third engine components in a heat exchange relationship.

8. The engine as set forth in claim **6**, wherein the second water passage terminates at a discharge port that extends through an outer surface of an upper portion of the outboard motor.

9. An outboard motor comprising an engine body, a plurality of engine components disposed around the engine body, and a water cooling system comprising a water inlet disposed lower than the engine body so as to introduce the water into the cooling system, a first water passage arranged to cool the engine body and a second water passage arranged to cool the plurality of engine components, the first water passage comprising a first water discharge port positioned closer to the water inlet than to the engine body and the second water passage comprising a second water discharge port positioned closer to the engine body than to the water inlet.

10. The outboard motor as set forth in claim **9** additionally comprising a protective cowling surrounding the engine body and the engine components, wherein the second water discharge port is defined at the protective cowling.

11. The outboard motor as set forth in claim **9**, wherein at least two of the plurality of engine components through which the second water passage extends are disposed on opposing sides of the engine body relative to each another.

12. The internal combustion engine as set forth in claim **9**, wherein the plurality of engine components are made of a metal material, the second water passage at least in part is defined by tubular members made of a corrosion-resistant material, and the respective tubular members are at least partially embedded in respective bodies of the engine components.

13. The outboard motor as set forth in claim **9**, wherein the second water passage branches off from the first water passage upstream the engine body.

14. The engine as set forth in claim **9**, wherein the second water passage terminates at said second water discharge port and said second water discharge port extends through an outer surface of an upper portion of the outboard motor.

15. An internal combustion engine for an outboard motor comprising an engine body, at least three engine components disposed around the engine body, and a water cooling system for cooling both the engine body and the engine components, the cooling system comprising a first water passage arranged to cool the engine body, and a second water passage branching off from the first water passage upstream of the engine body and extending through the at least three engine components, a first of the at least three engine components being generally positioned above the engine body, and a second and a third of the at least three engine components being generally positioned on a different side of the engine body relative to one another.

16. The engine as set forth in claim **15**, wherein the second water passage terminates at a discharge port that extends through an outer surface of an upper portion of the outboard motor.

17. The engine as set forth in claim **15**, wherein the second water passage extends through the engine components in series.

18. The engine as set forth in claim **15**, wherein at least one of the second engine component and the third engine component is disposed upstream of the first engine component.

19. The engine as set forth in claim **15**, wherein at least one of the second engine component and the third engine component is disposed downstream of the first engine component.

20. The engine as set forth in claim **15**, wherein the first engine component is made of metal material, the second

water passage in part is defined by a tubular member made of corrosion-resistant material, and the tubular member is at least partially embedded in a body of the first engine component.

21. The engine as set forth in claim **15**, wherein the first engine component comprises a power generator.

22. The engine as set forth in claim **15**, wherein at least one of the second engine component and the third engine component is made of metal material, the second water passage at least in part is defined by a tubular member made of corrosion-resistant material, and the tubular member is at least partially embedded in a body of the engine component.

23. The engine as set forth in claim **15**, wherein both the sides of the engine body are lateral sides thereof located opposite to one another.

24. The engine as set forth in claim **15**, wherein each one of the first and second water passages comprises a separate water discharge port relative to each other.

25. The engine as set forth in claim **15** additionally comprising at least one combustion chamber defined within the engine body, and an air intake system arranged to introduce air to the combustion chamber, wherein one of the second engine component and the third engine component comprises an air intake conduit, and the second coolant passage extends through a body of the air intake conduit.

26. The engine as set forth in claim **25**, wherein the air intake conduit is made of a metal material, the second water passage at least in part is defined by a tubular member made of a corrosion-resistant material, and the tubular member is at least partially embedded in the body of the air intake conduit.

27. The engine as set forth in claim **15** additionally comprising at least one combustion chamber defined within the engine body, and a fuel supply system arranged to supply fuel to the combustion chamber, wherein at least one of the second engine component and the third engine component comprises a fuel delivery conduit, and the second coolant passage extends through a body of the fuel delivery conduit.

28. The engine as set forth in claim **27**, wherein the fuel delivery conduit is made of a metal material, the second water passage at least in part is defined by a tubular member made of a corrosion-resistant material, and the tubular member is at least partially embedded in the body of the fuel delivery conduit.

29. The engine as set forth in claim **27**, wherein the fuel delivery conduit defines a fuel passage extending therethrough, and the second water passage extends along at least a portion of the fuel passage.

30. The engine as set forth in claim **27**, wherein the fuel supply system comprises a fuel injector arranged to spray the fuel toward the combustion chamber, a fuel rail arranged to support the fuel injector, and the fuel delivery conduit is defined in the fuel rail.

31. The engine as set forth in claim **15** additionally comprising a lubrication system arranged to lubricate at least one inner portion of the engine body, wherein one of the first engine component and the second engine component comprises a lubricant delivery conduit, and the second water passage extends through a body of the lubricant delivery conduit.

32. The engine as set forth in claim **31**, wherein the lubricant delivery conduit is made of a metal material, the second water passage at least in part is defined by a tubular member made of a corrosion-resistant material, and the tubular member is at least partially embedded in the body of the lubricant delivery conduit.

33. The engine as set forth in claim **31**, wherein the lubrication system comprises a filter assembly, and the lubricant delivery conduit is defined in the filter assembly.

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